PoCoPo

Handheld Pin-based Shape Display for Haptic Rendering in Virtual Reality

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東京大学
THE UNIVERSITY OF TOKYO

*The first two authors contributed equally to this work.

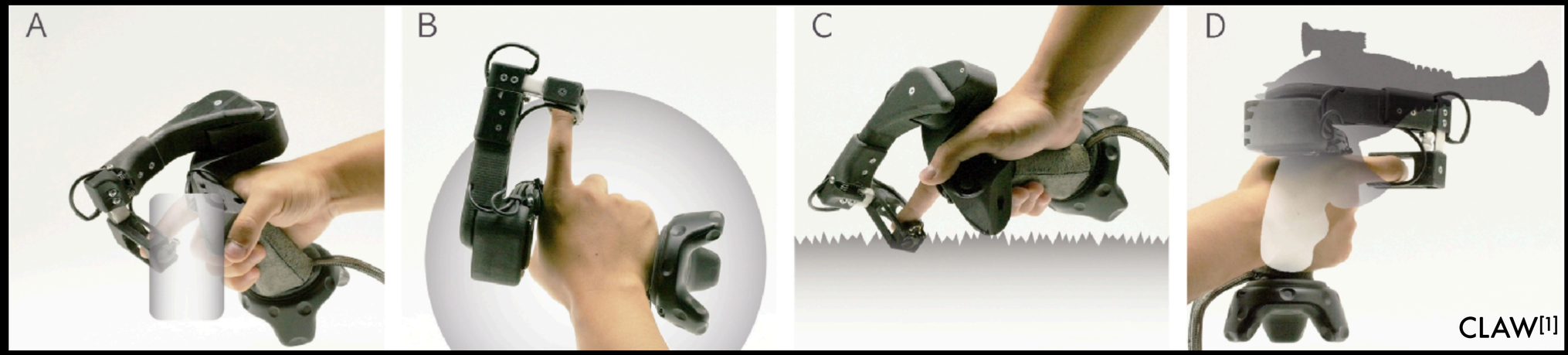
PoCoPo is a ***first*** handheld pin-based shape display that can render various 2.5D shapes in hand.

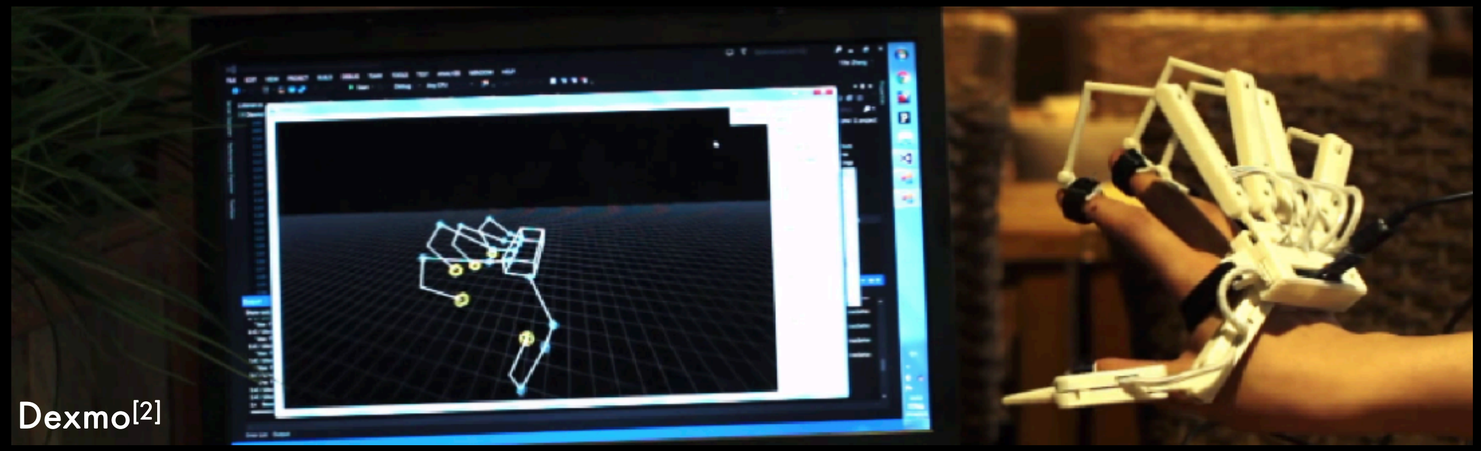
PoCoPo = POp-up COntrolable Pins On palm

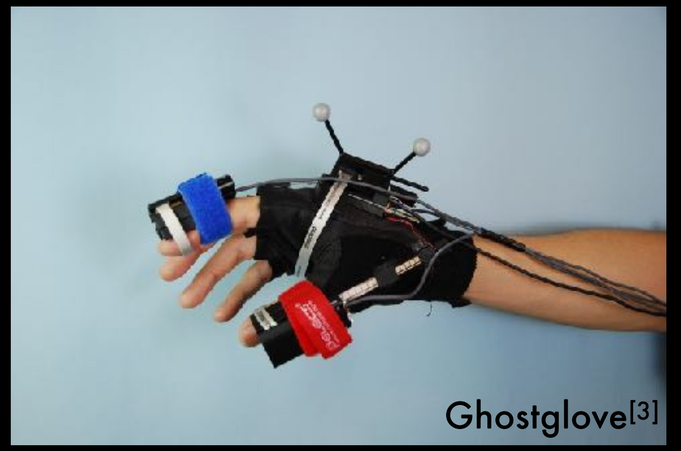
Motivation

Reproduction of shape sensation in VR is still ***under development***

VR Device for Shape Rendering with Haptic Feedback







[1] Inrak Choi, et al. CLAW: A Multifunctional Handheld Haptic Controller for Grasping, Touching, and Triggering in Virtual Reality. CHI '18.
[2] Xiaochi Gu, et al. Dexmo: An Inexpensive and Lightweight Mechanical Exoskeleton for Motion Capture and Force Feedback in VR. CHI '16.
[3] Kouta Minamizawa, et al. Ghostglove: Haptic existence of the virtual world. ACM SIGGRAPH 2008 New Tech Demos.

VR Device for Shape Rendering with Haptic Feedback

Simple mechanisms to provide force feedback to hands

but...
Lack of ***skin contact sensation***

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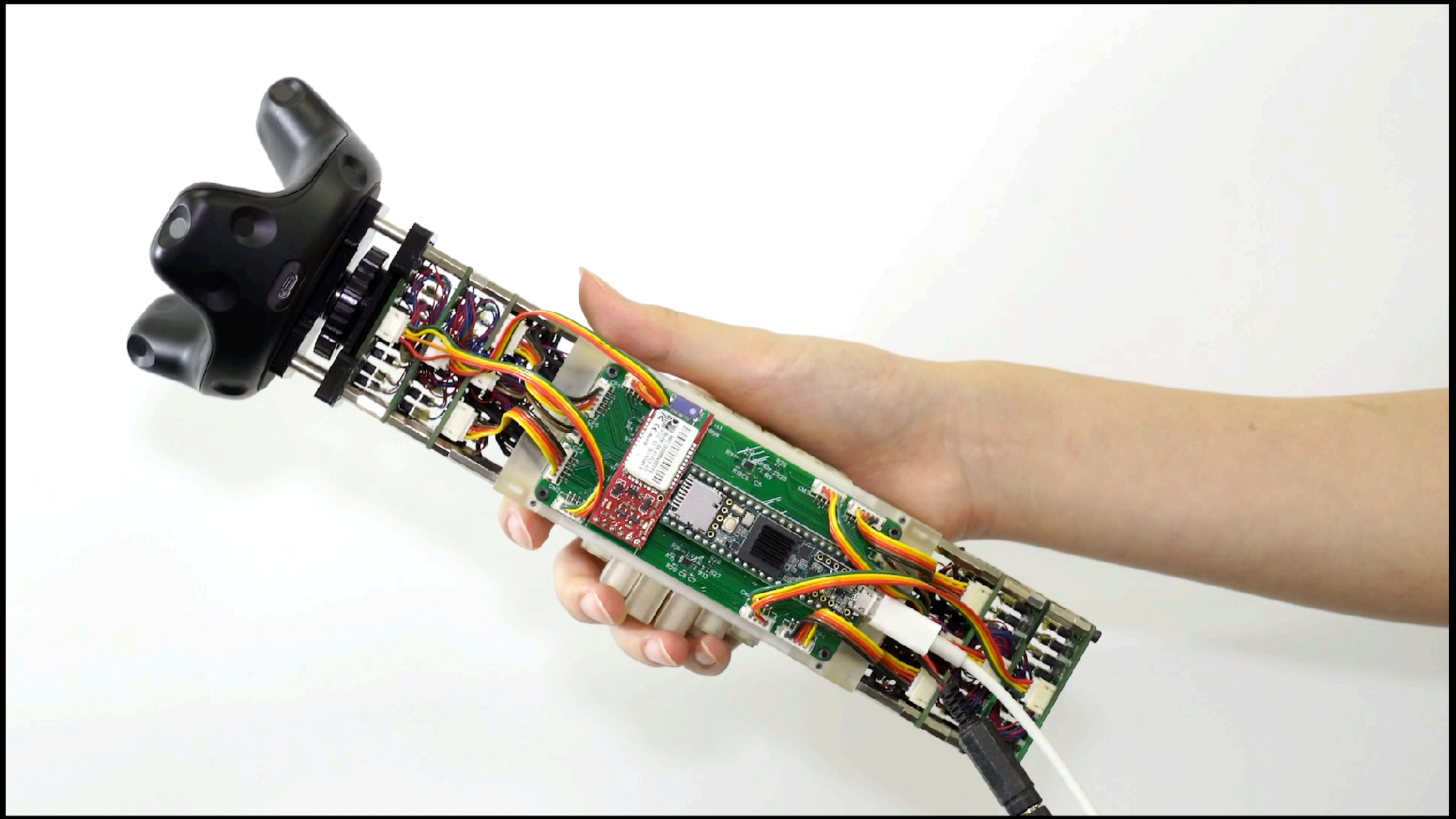
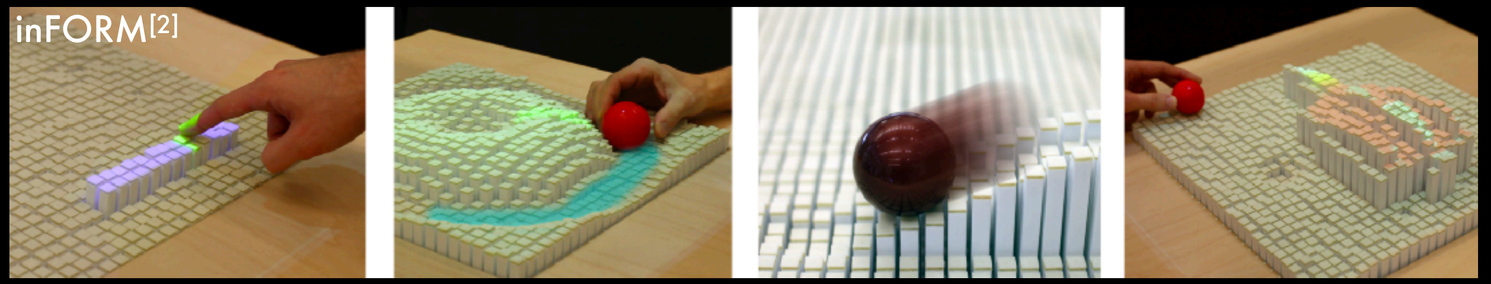
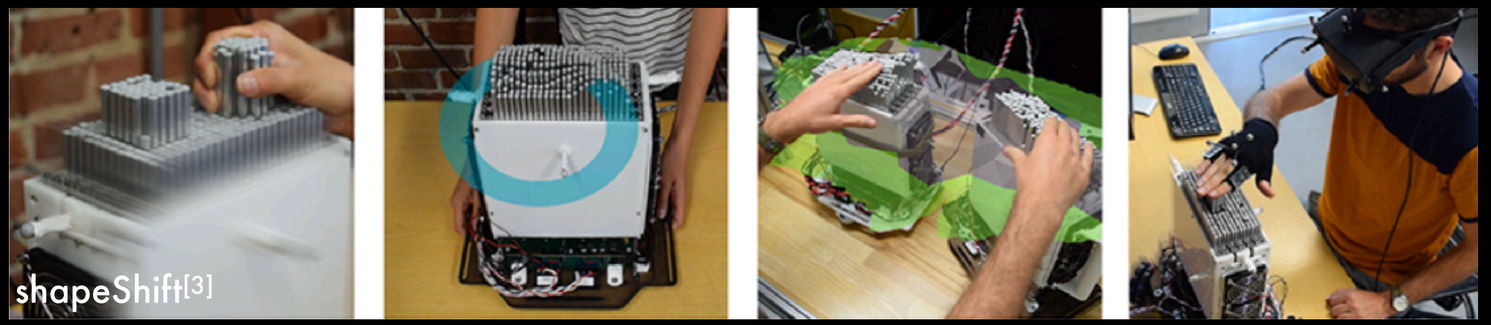


Pin-based Shape Display





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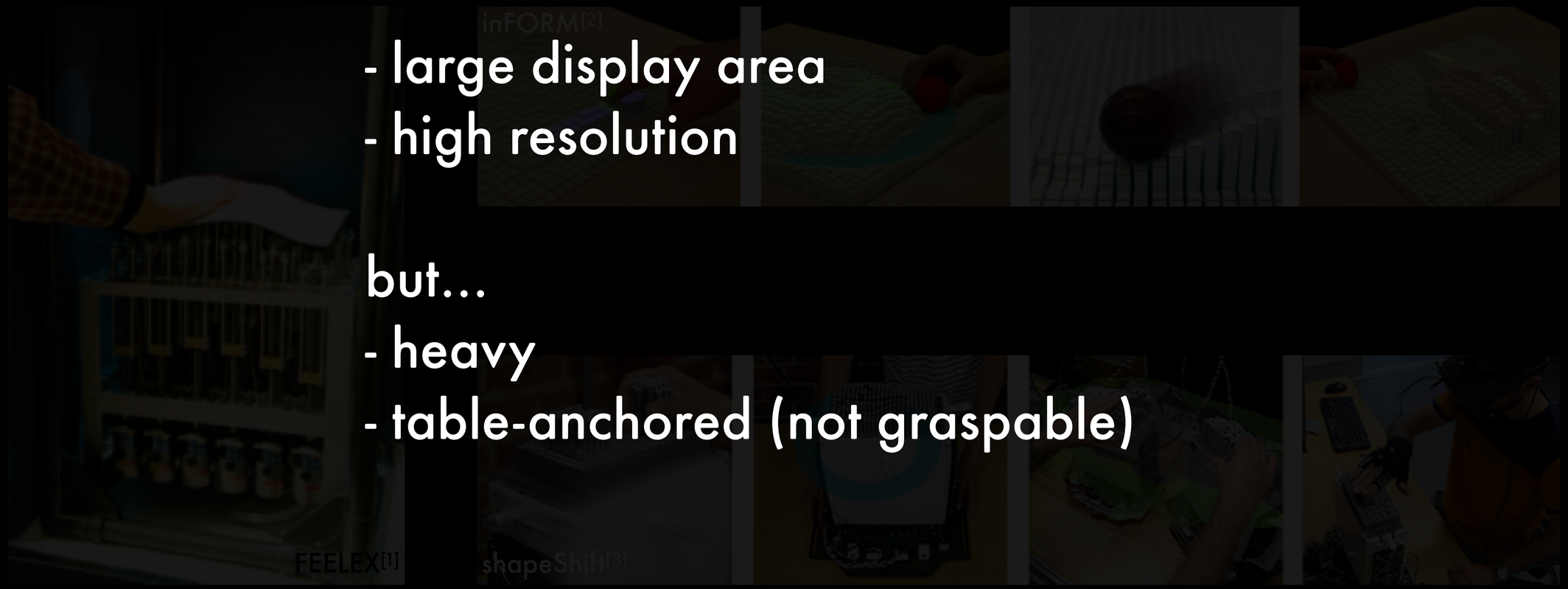

- large display area
- high resolution

but...
- heavy
- table-anchored (not graspable)

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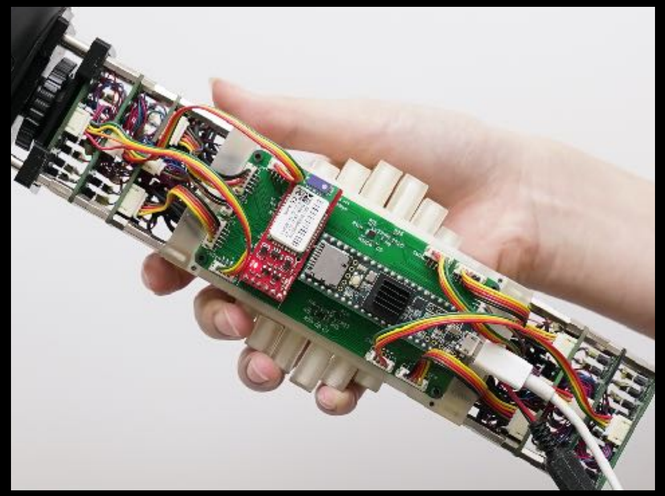
Haptic Edge Display[1]

1.5D shape

free-form

static/dynamic shape

backdrivable



PoCoPo

2.5D shape

free-form

static/dynamic shape

non-backdrivable

PuPoP[2]

3D shape

pre-defined
(subject to attached airbag)

static shape

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Haptic Edge Display[1]

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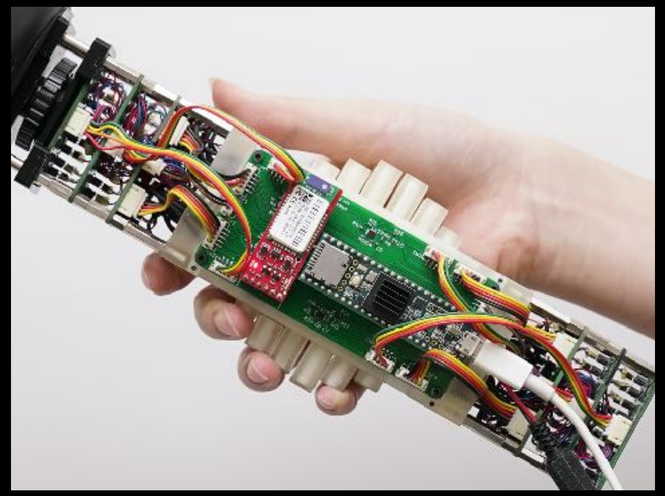

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Implementation

Challenge:

How to make a pin-based shape display into a ***handheld size***?

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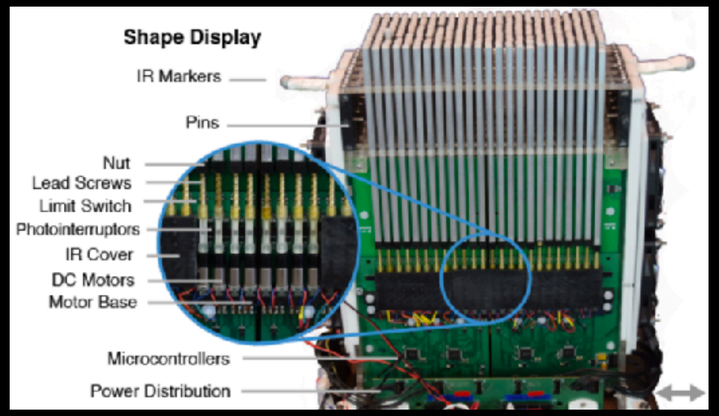
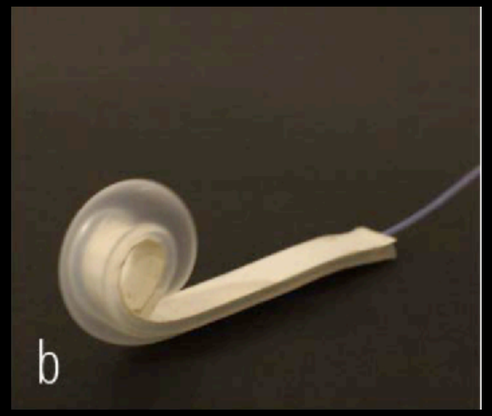


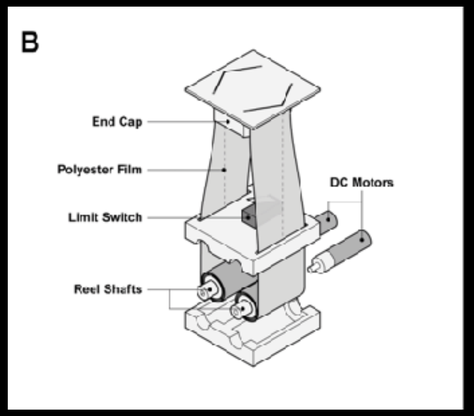
Lead screw linear actuator[1]

mechanism gets larger along motor direction



Pneumatic actuator[2]

less mobility



Reel-based linear actuator[3]

insufficient power

[1] Alexa F. Siu, et al. shapeShift: 2D Spatial Manipulation and Self-Actuation of Tabletop Shape Displays for Tangible and Haptic Interaction. CHI '18.
[2] Lining Yao, et al. PneUI: pneumatically actuated soft composite materials for shape changing interfaces. UIST '13.
[3] Ryo Suzuki, et al. ShapeBots: Shape-changing Swarm Robots. UIST '19.

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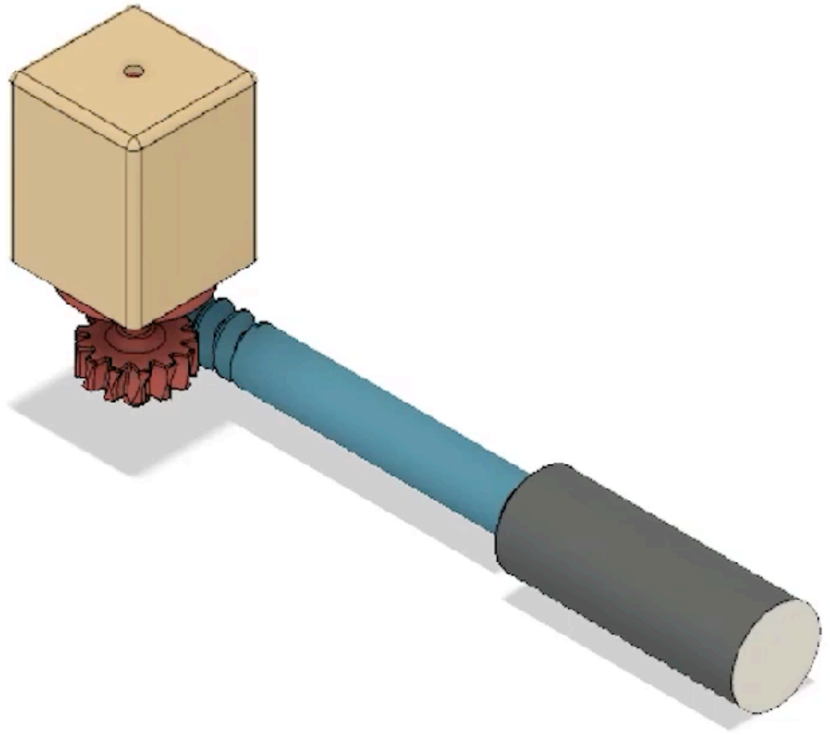
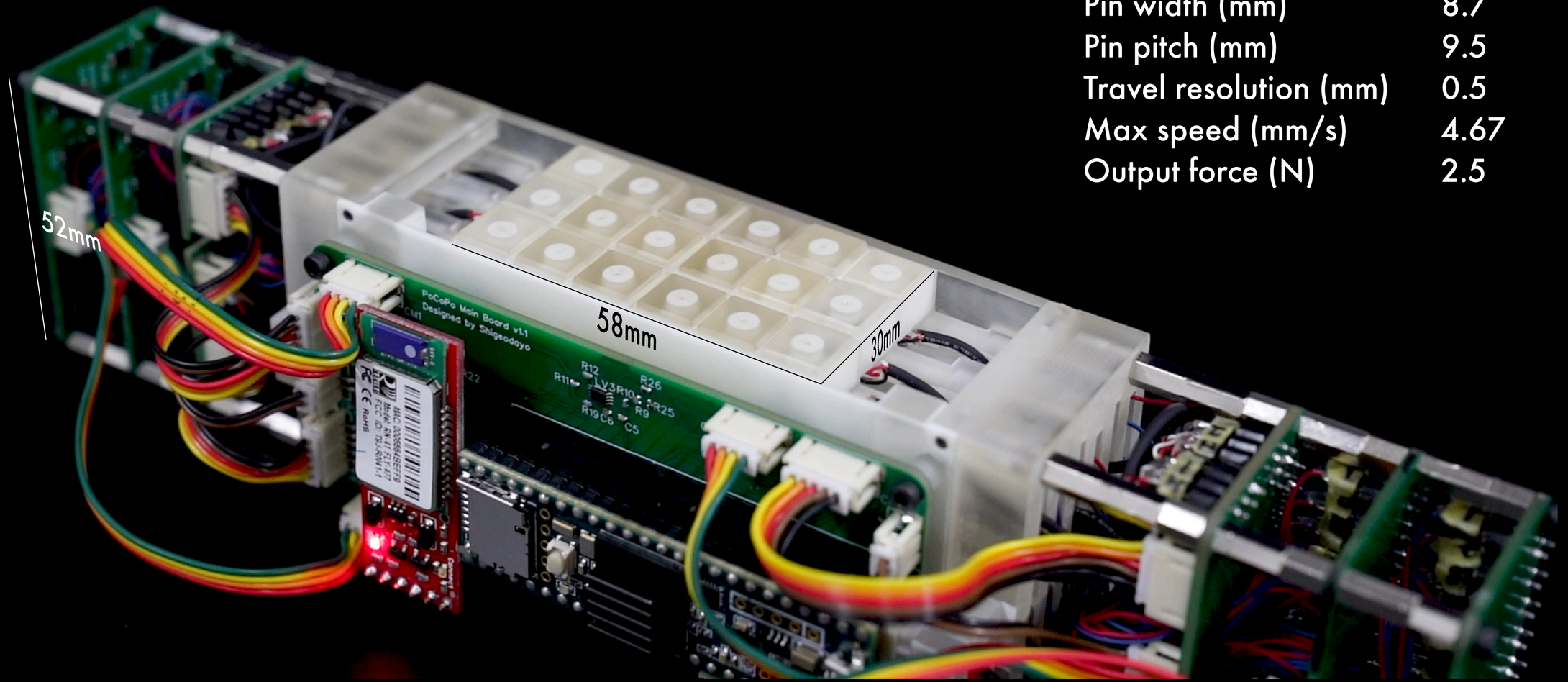
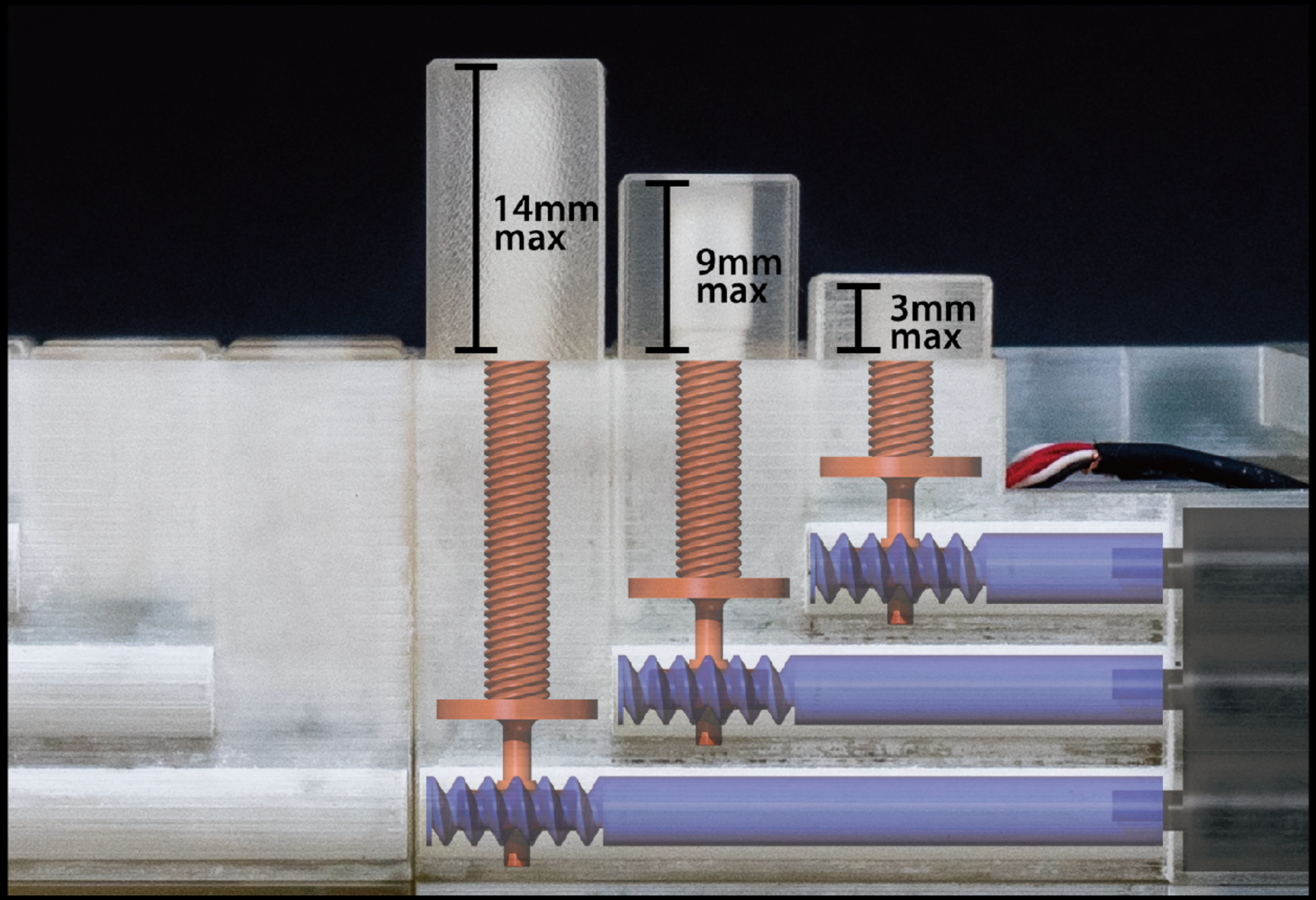
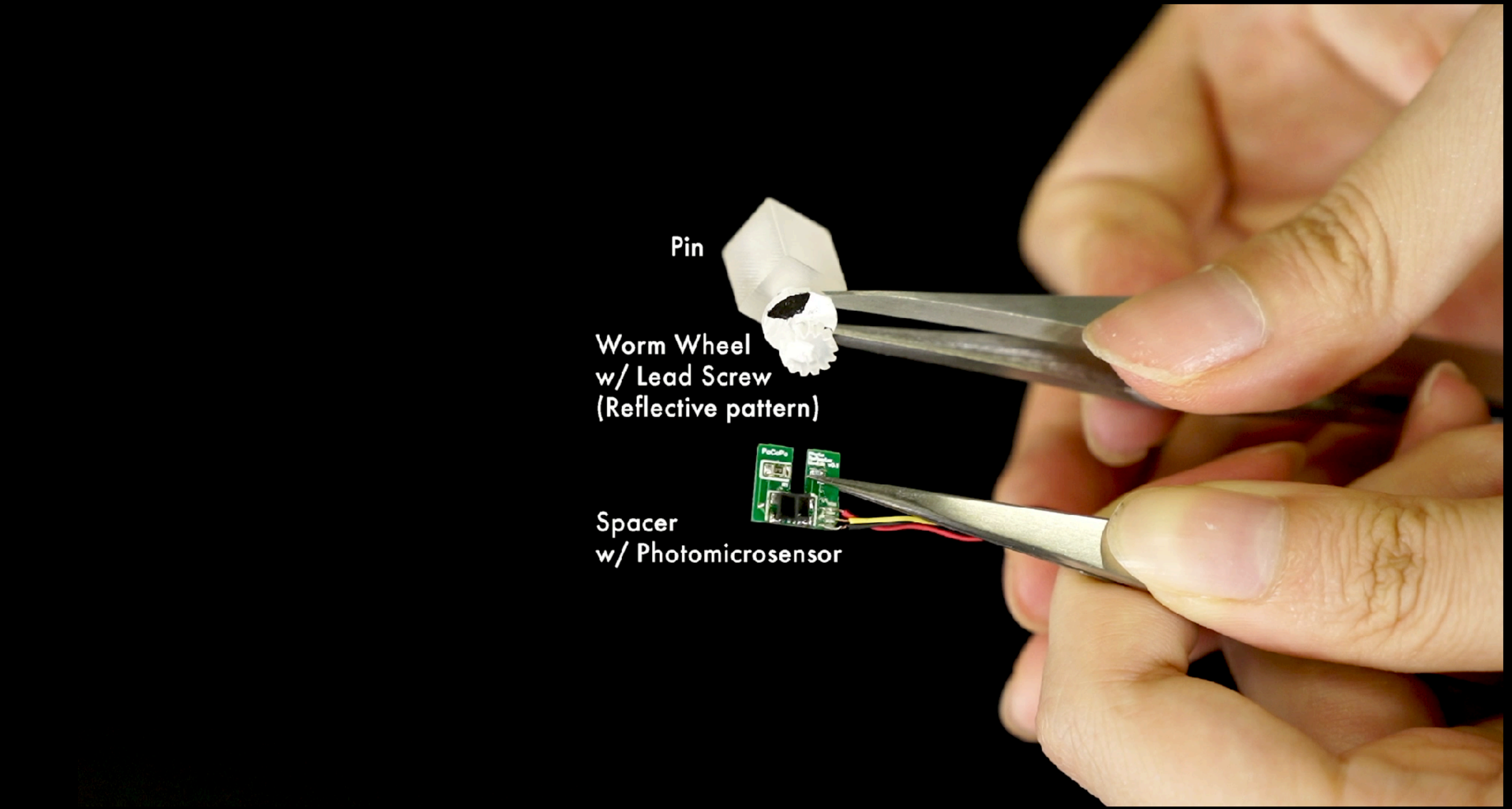


Number of pins (2 sides)	36
Pin width (mm)	8.7
Pin pitch (mm)	9.5
Travel resolution (mm)	0.5
Max speed (mm/s)	4.67
Output force (N)	2.5




14mm
max
9mm
max
3mm
max


Pin
Worm Wheel
w/ Lead Screw
(Reflective pattern)
Spacer
w/ Photomicrosensor

Wires/pin:

3 wires for photomicrosensor (Vcc, GND, signal)

2 wires for motor (out1, out2)

photomicrosensor on encoder board
(EE-SY193 by omron[1])

motor
(Sub-Micro Plastic Planetary Gearmotor by Pololu[2])

[1] https://www.omron.co.jp/ecb/product-detail?partNumber=EE-SY193
[2] https://www.pololu.com/product/2357

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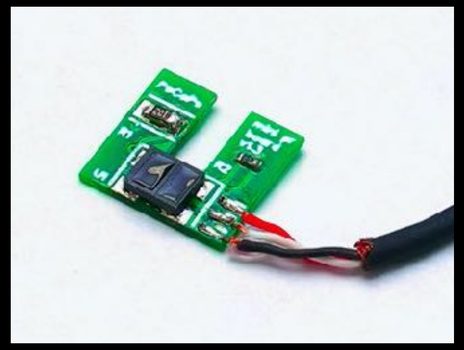
In total:

180 wires = 5 wires/pin x 36 pins



photomicrosensor on encoder board
(EE-SY193 by omron[1])

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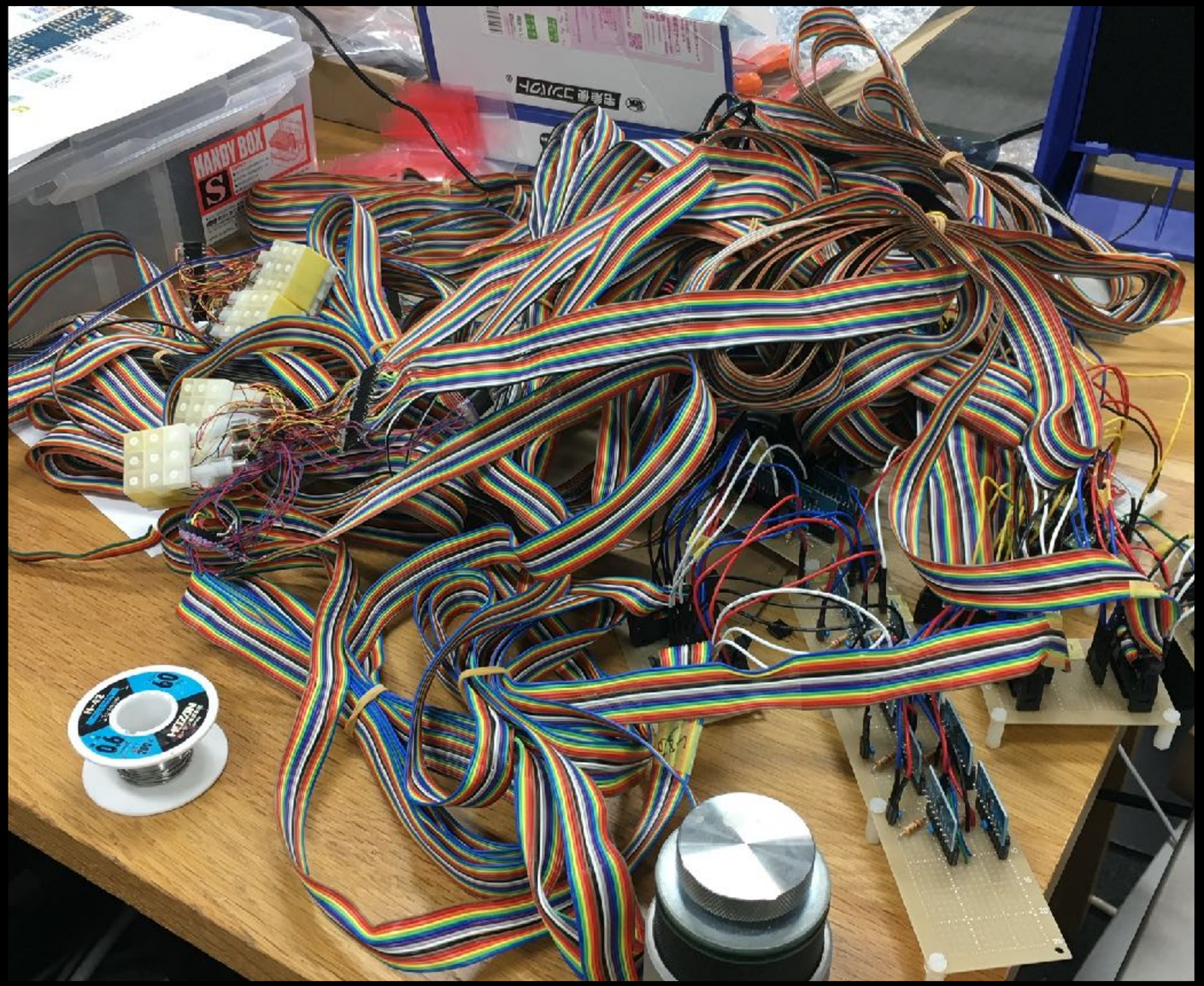

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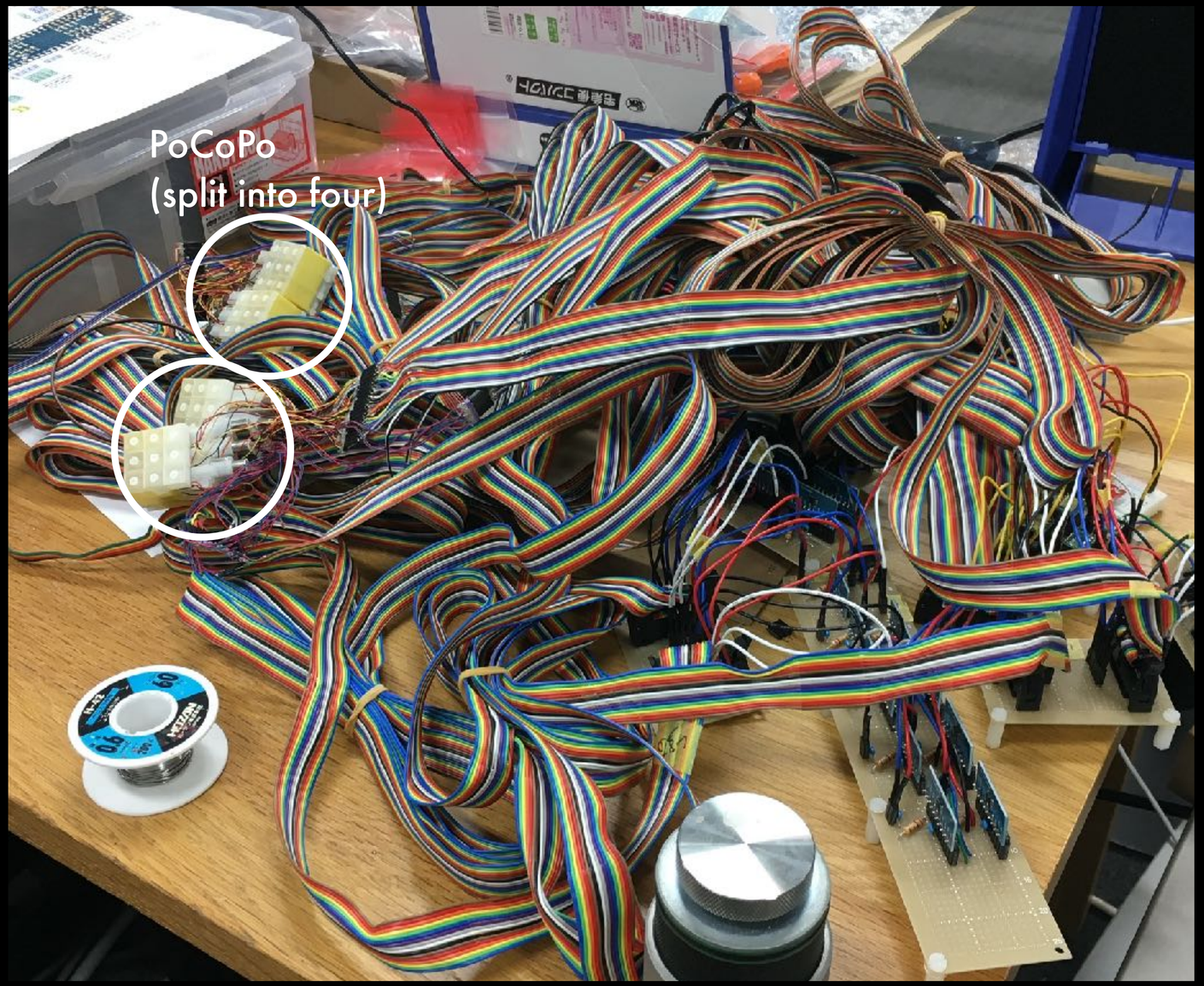
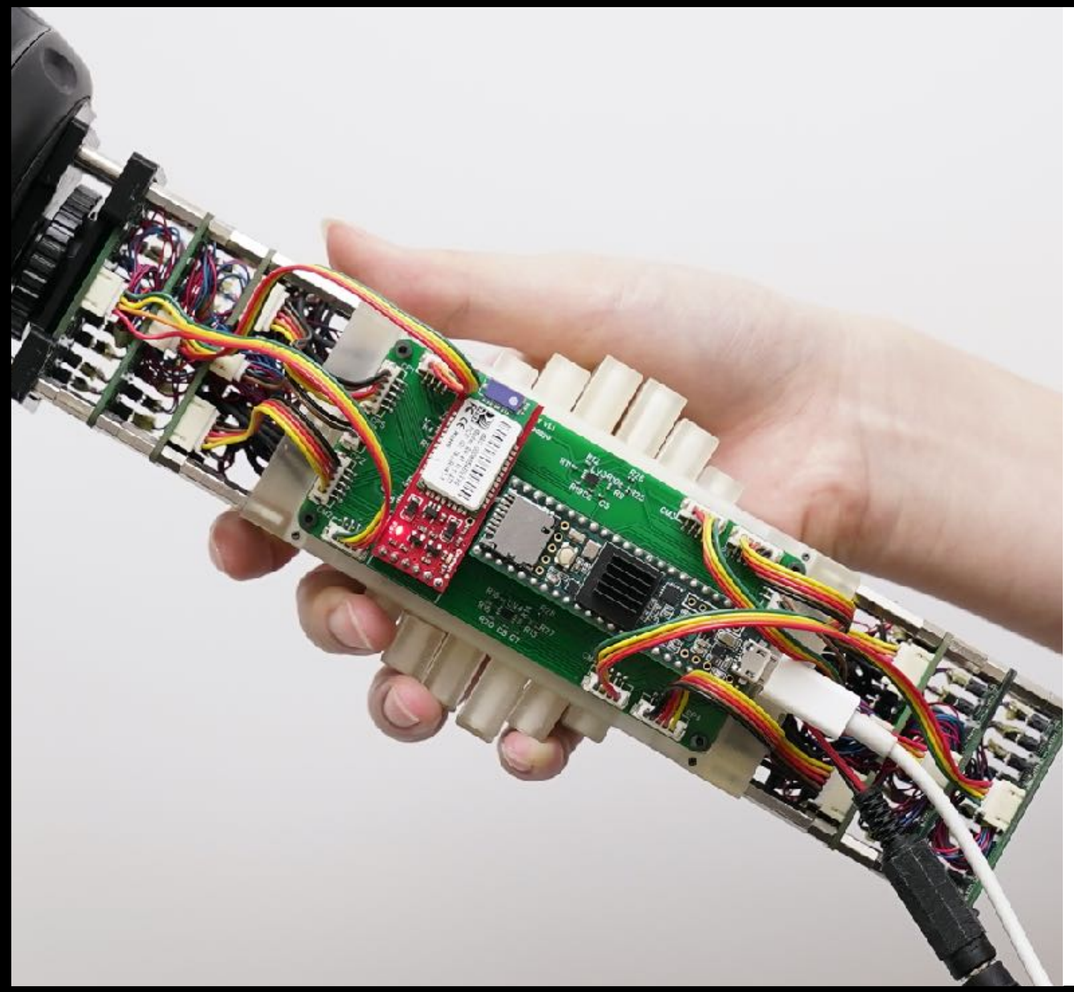
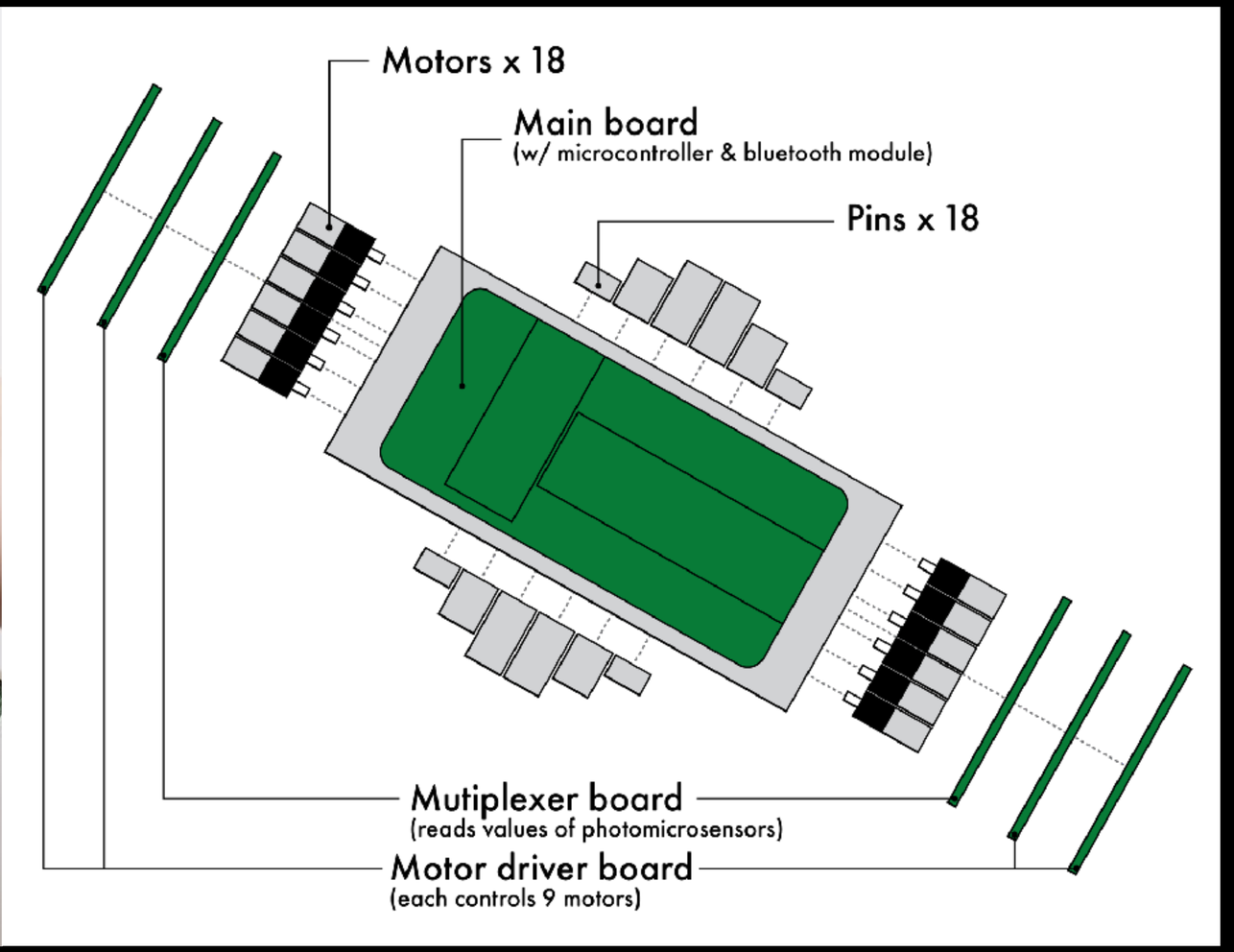
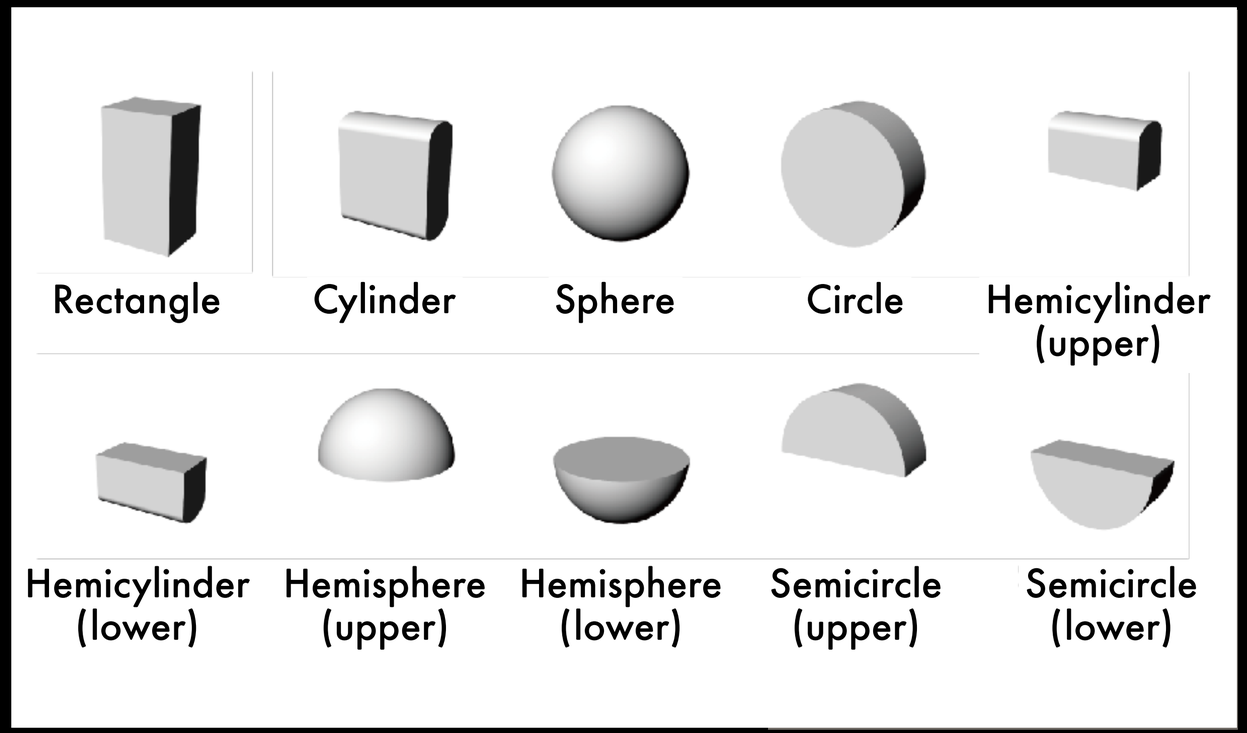




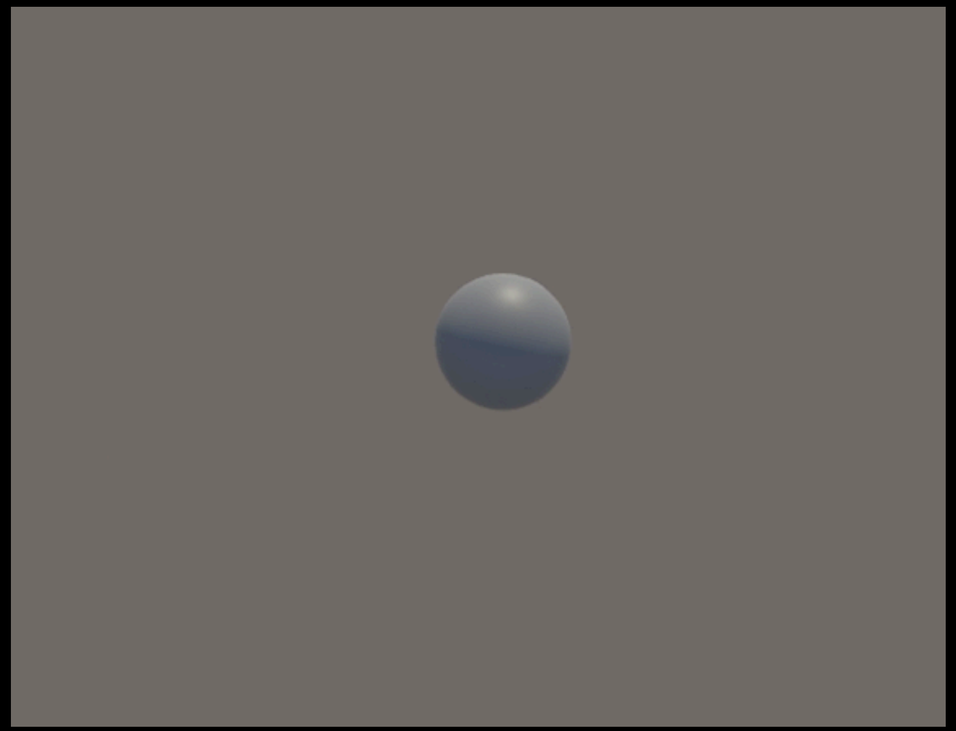

Motors x 18
Main board
(w/ microcontroller & bluetooth module)
Pins x 18
Mutiplexer board
(reads values of photomicrosensors)
Motor driver board
(each controls 9 motors)

User Study

Study 1:
Shape Prediction without Visual Information



Study 2:
Visual Size Acceptance Range



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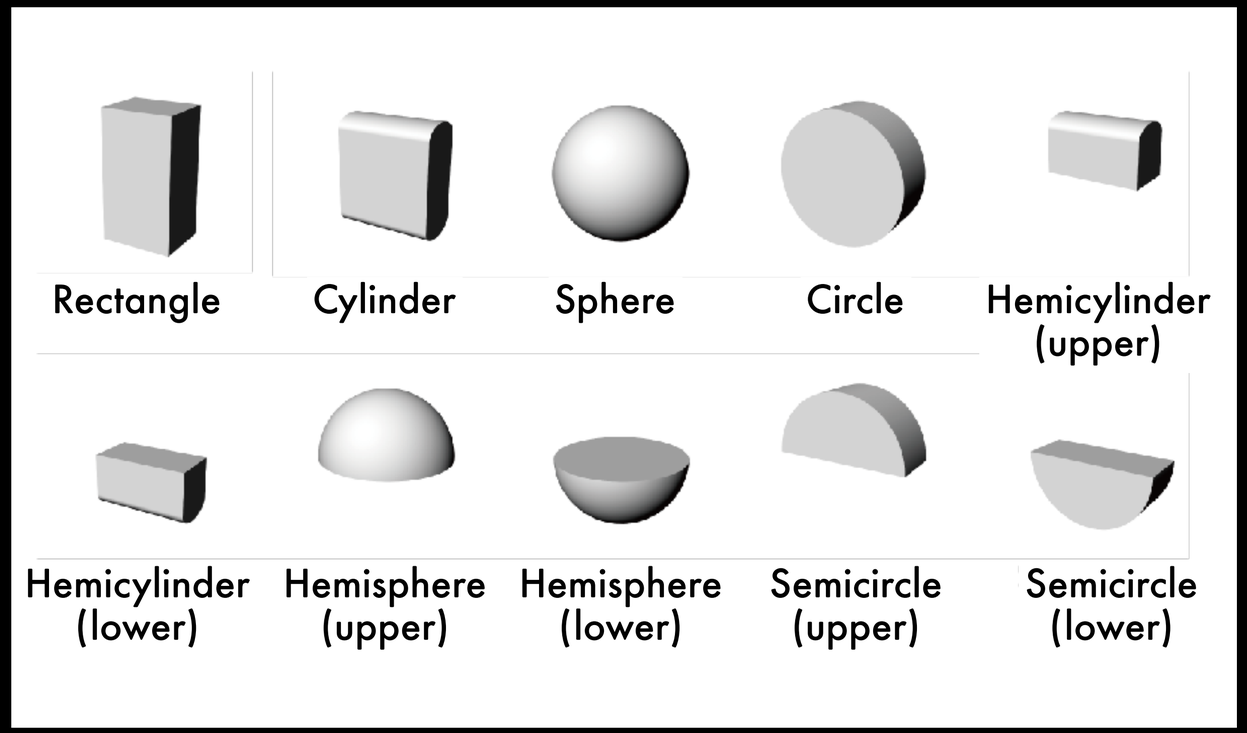
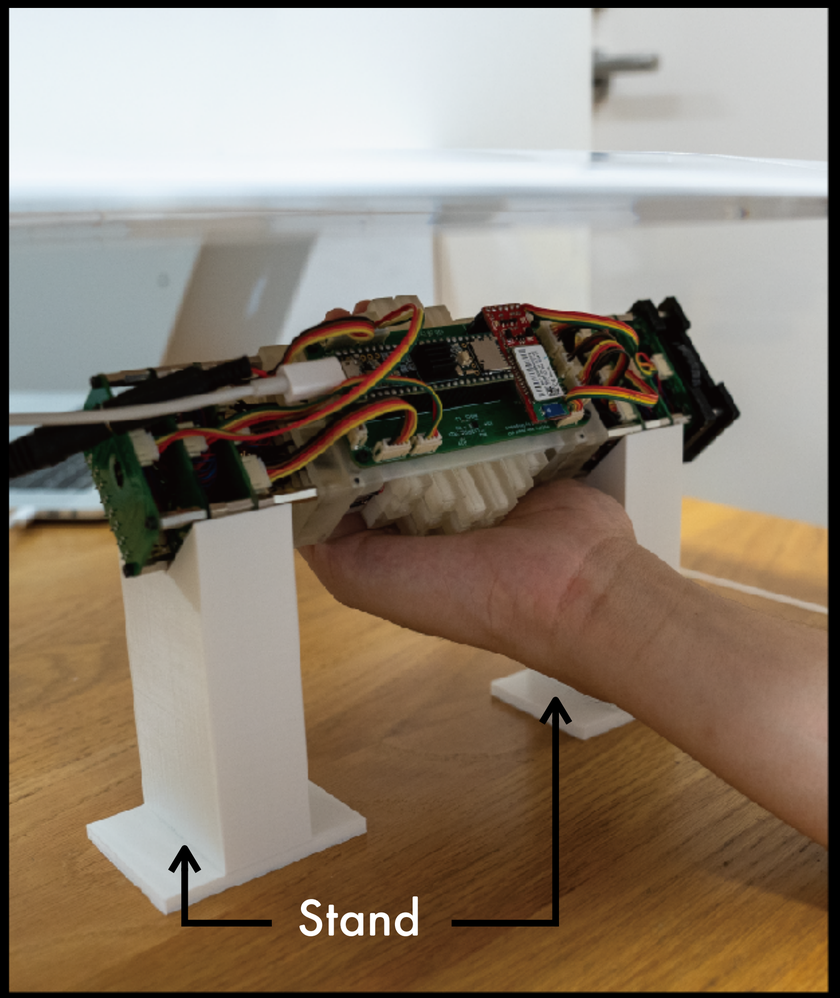


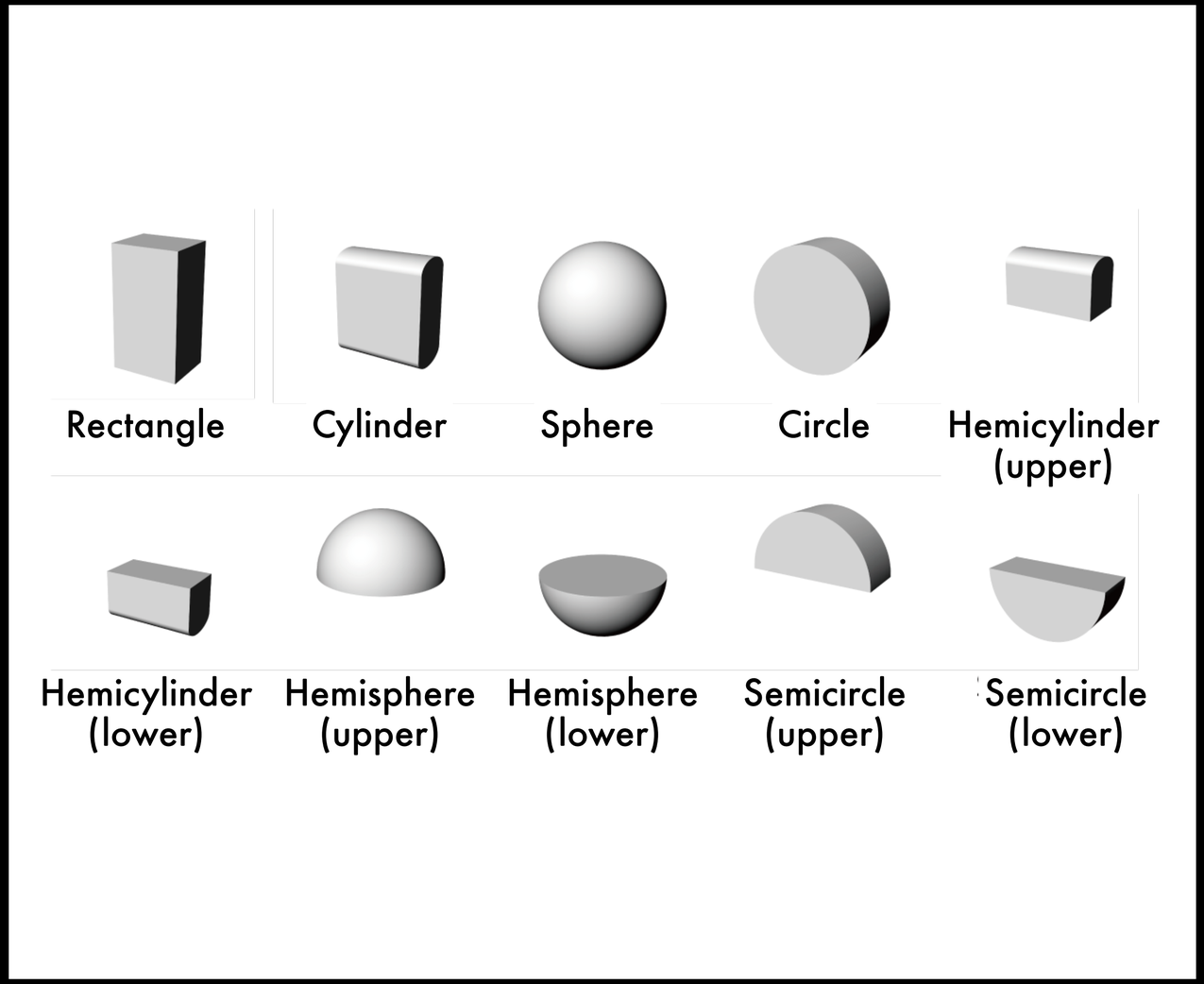
Study 2:
Visual Size Acceptance Range

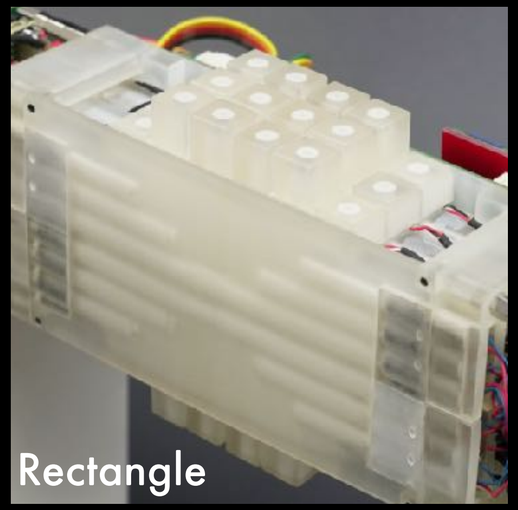
Please read our paper.

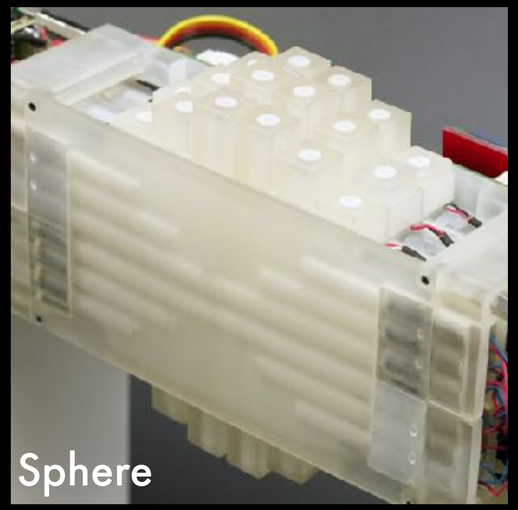
Study 1: Design & Setup

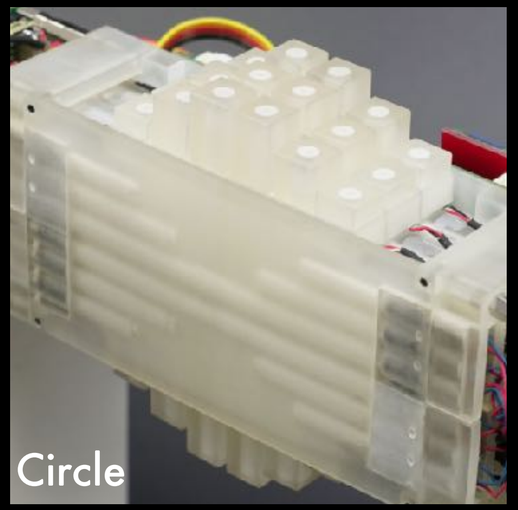


Study 1: Shapes Used in Study

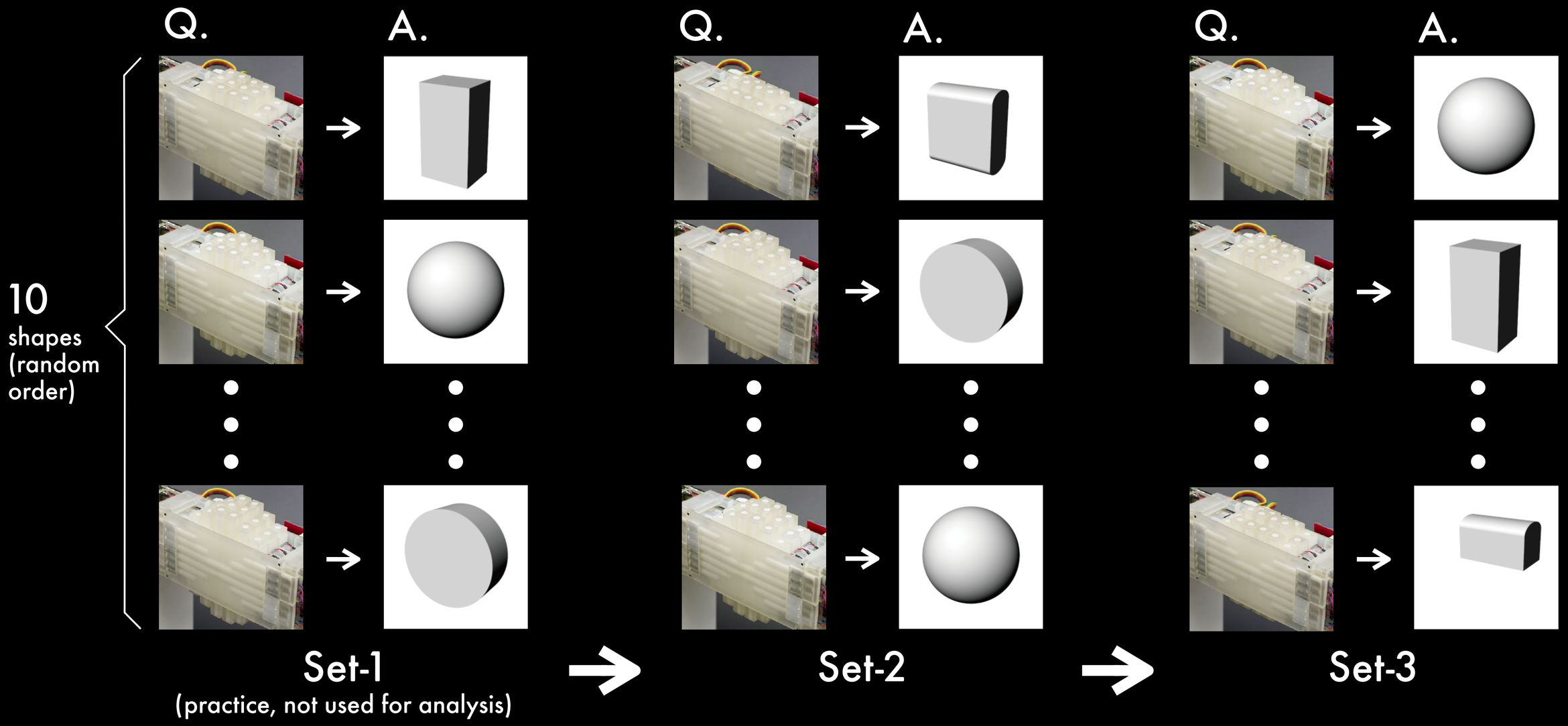




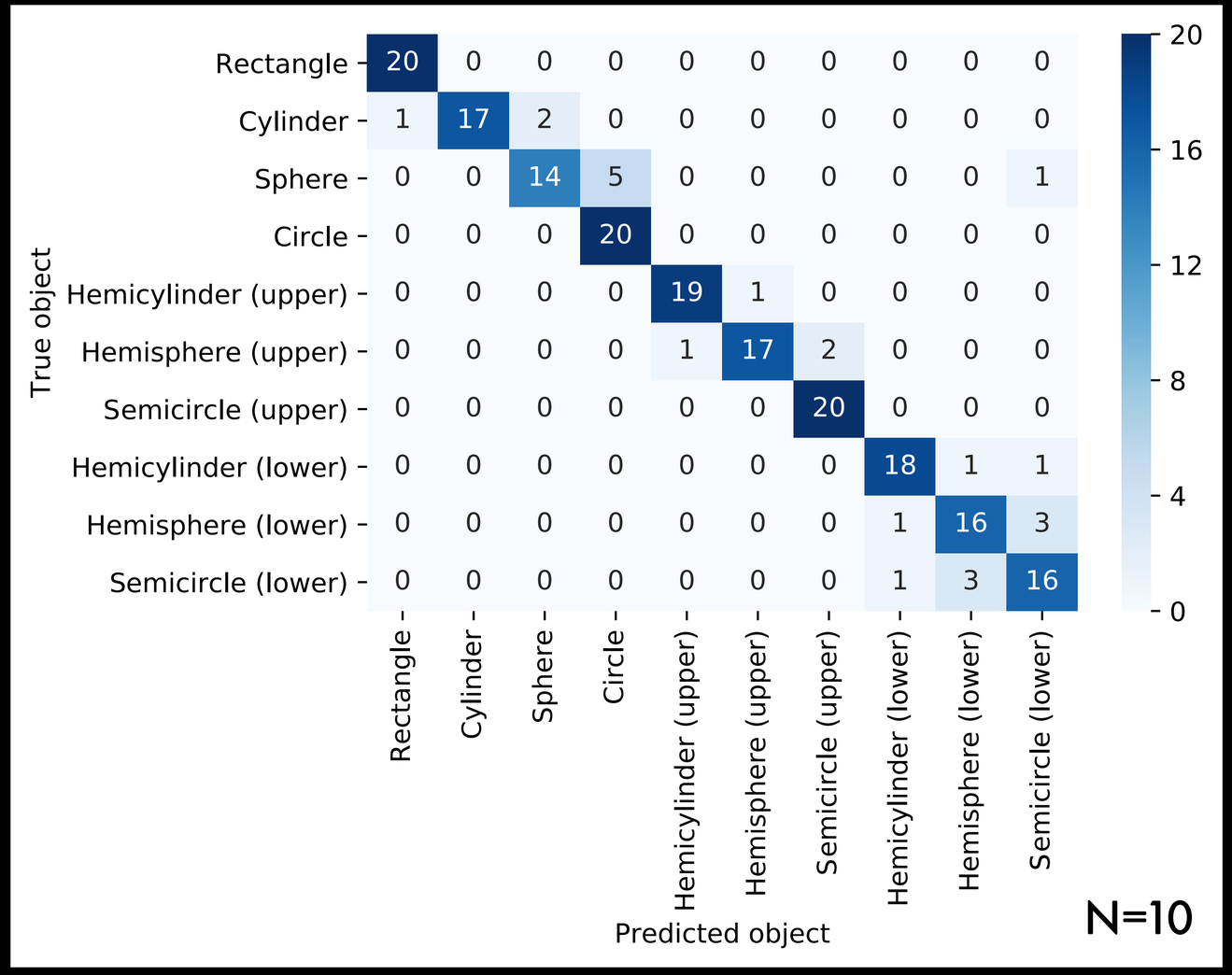




Study 1: Procedure



Study 1: Results & Discussions

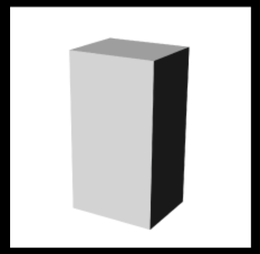


Max: 20 (= last 2 sets x 10 participants), Min: 0

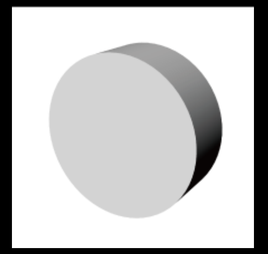
Average success rate: 88.5% (=177/200)

100% prediction rate:

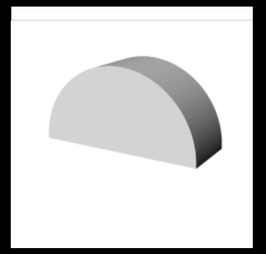
- Rectangle
- Circle
- Semicircle (upper)



Rectangle



Circle



Semicircle (upper)

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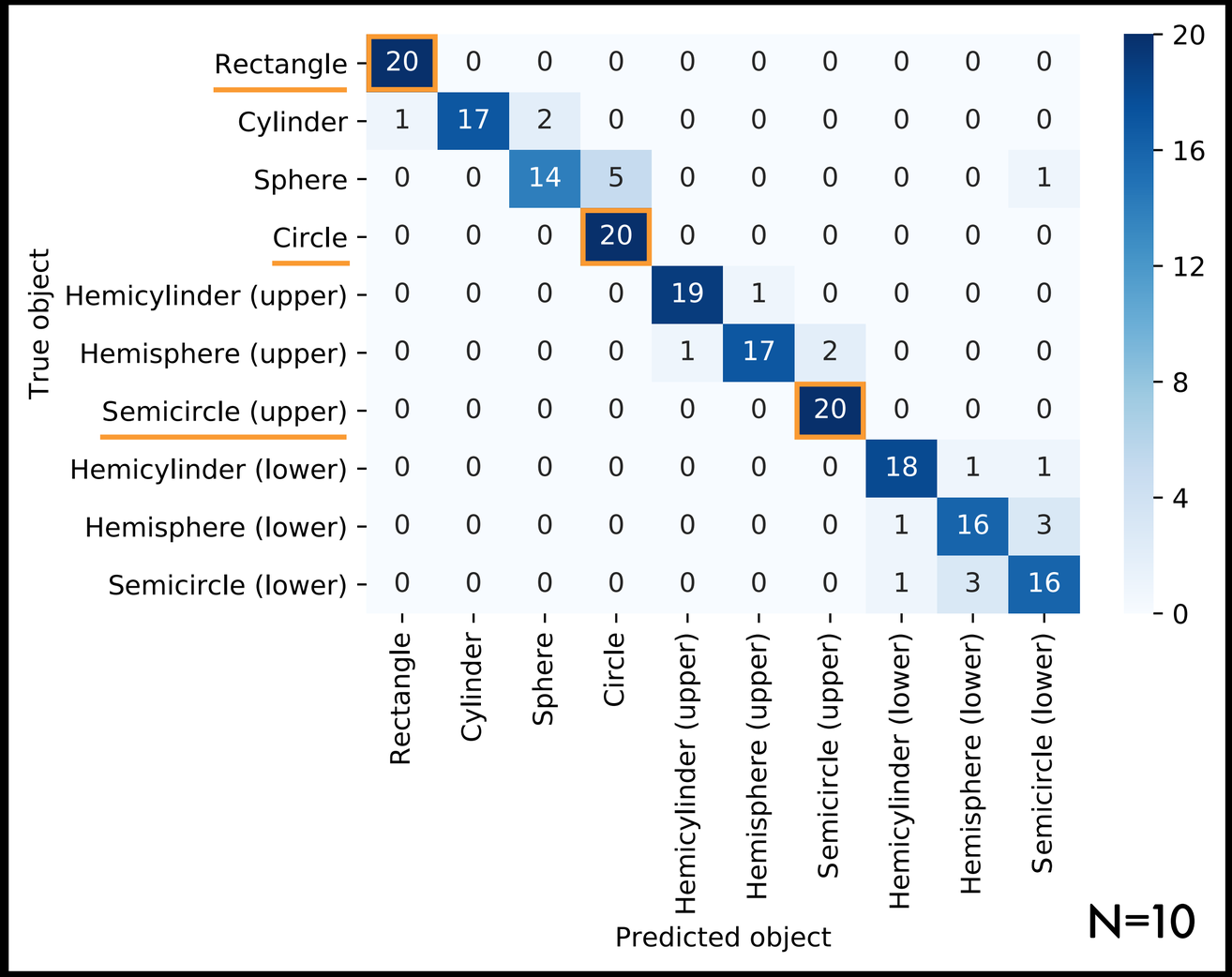

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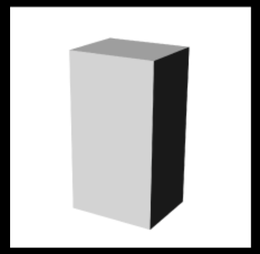

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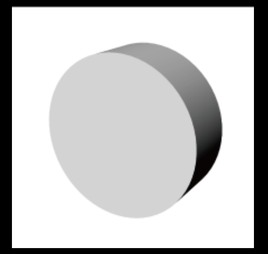
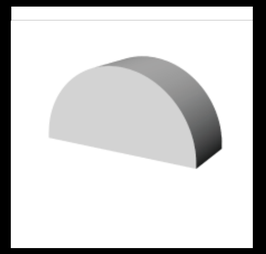


Circle



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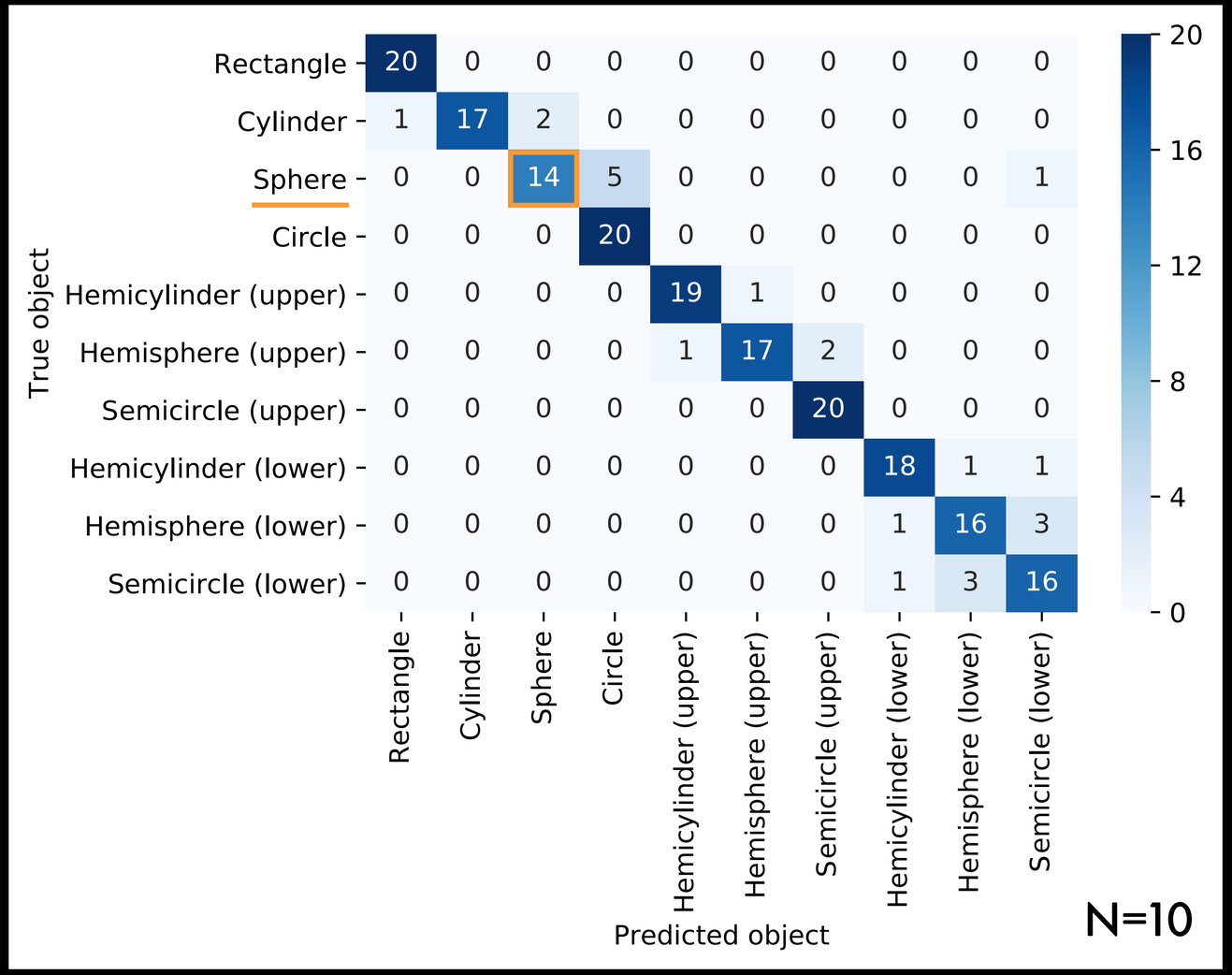
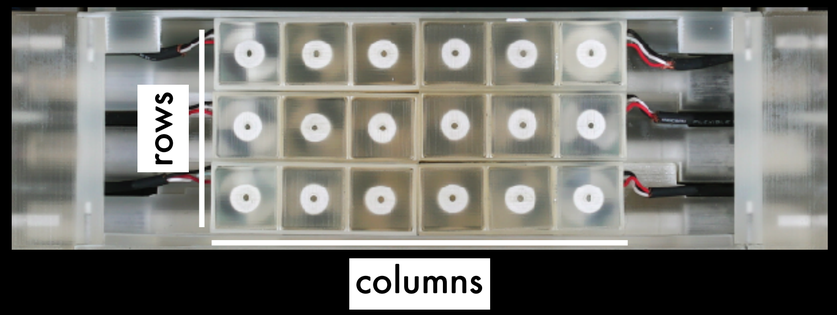


Lowest prediction rate:

- Sphere

Tend to be confused with Circle

P10:"Difficult to tell the difference between sphere and circle in rows."



Increasing the number of rows would improve prediction rates.

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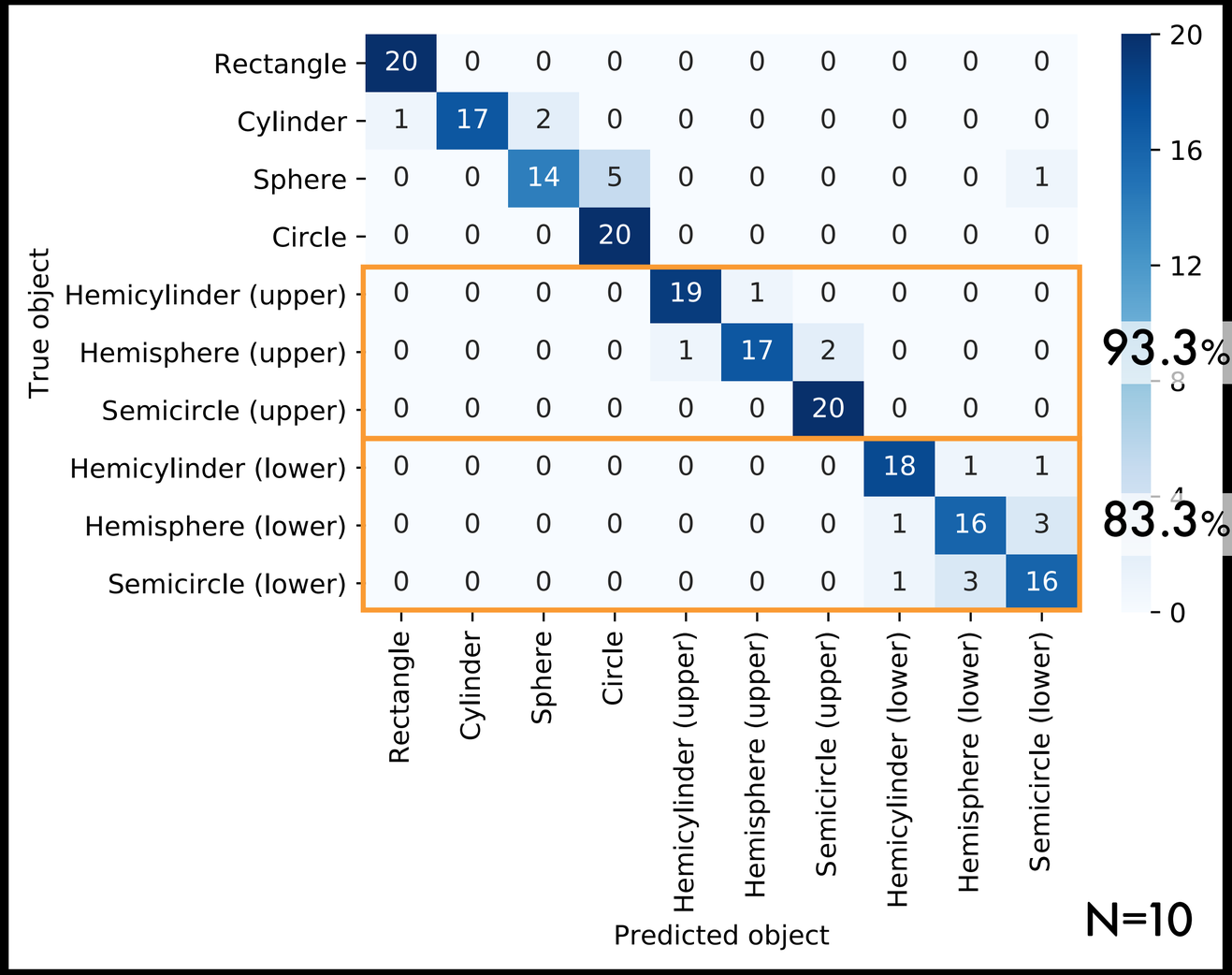

Prediction rate (upper): 93.3%

Prediction rate (lower): 83.3%

- Tendency to confuse Hemisphere (lower) & Semicircle (lower)

P5: "Difficult to distinguish the pin length with the palm base."

Not important to increase pin resolution for palm base

- Palm base is not sensitive

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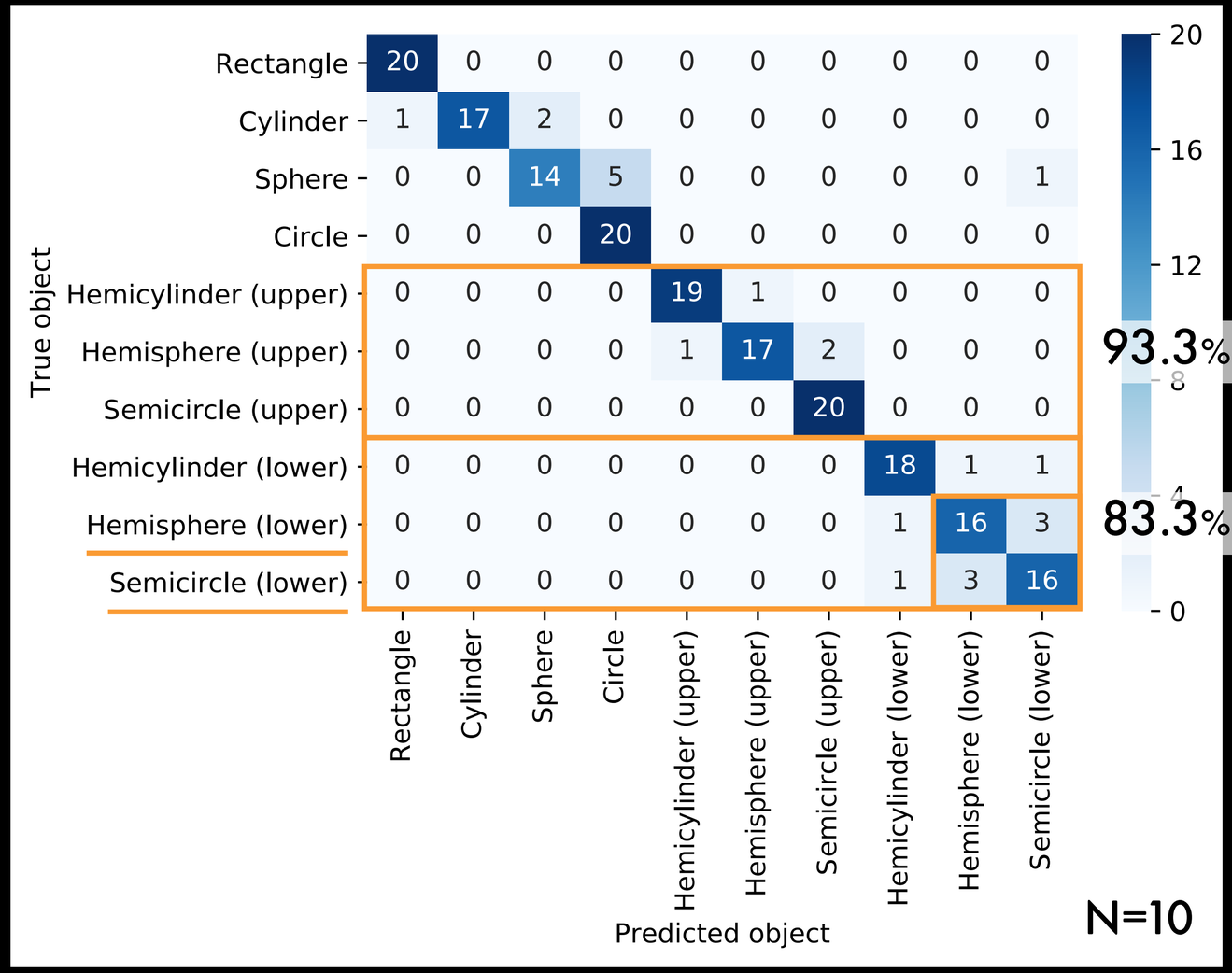

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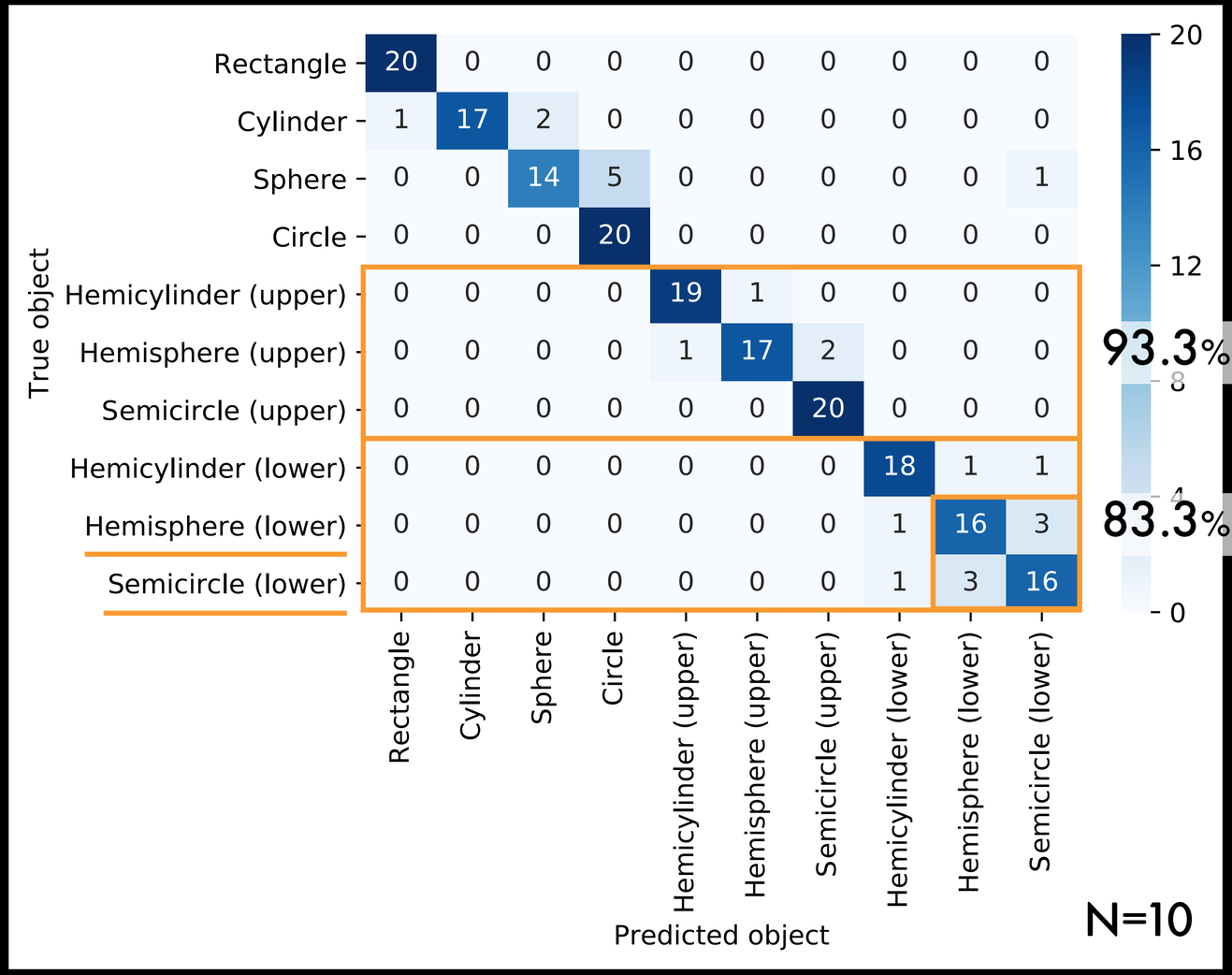

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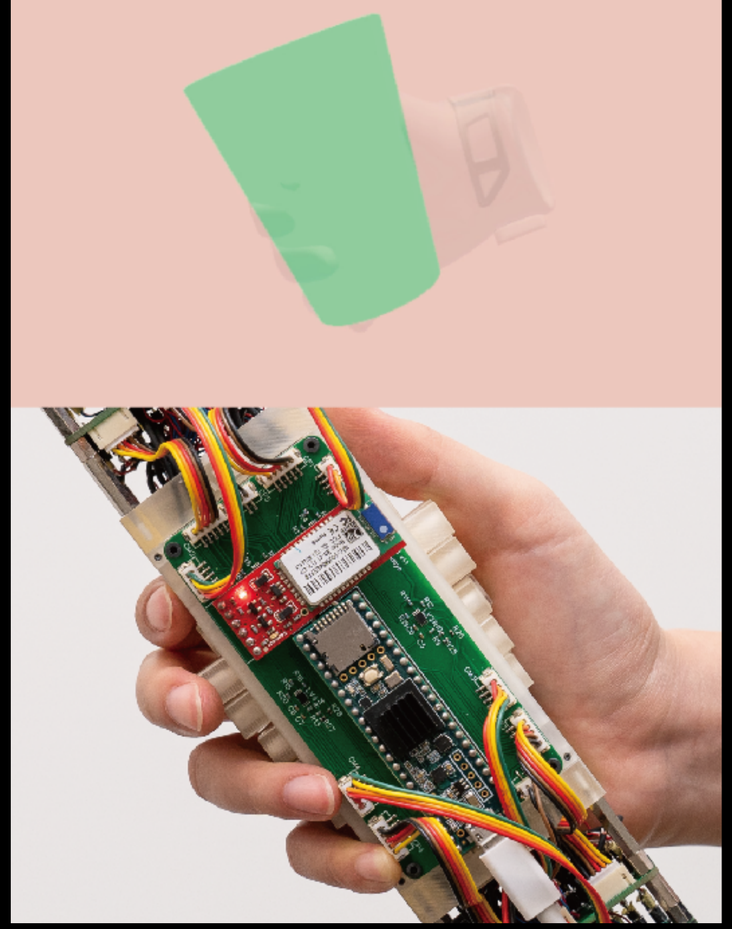
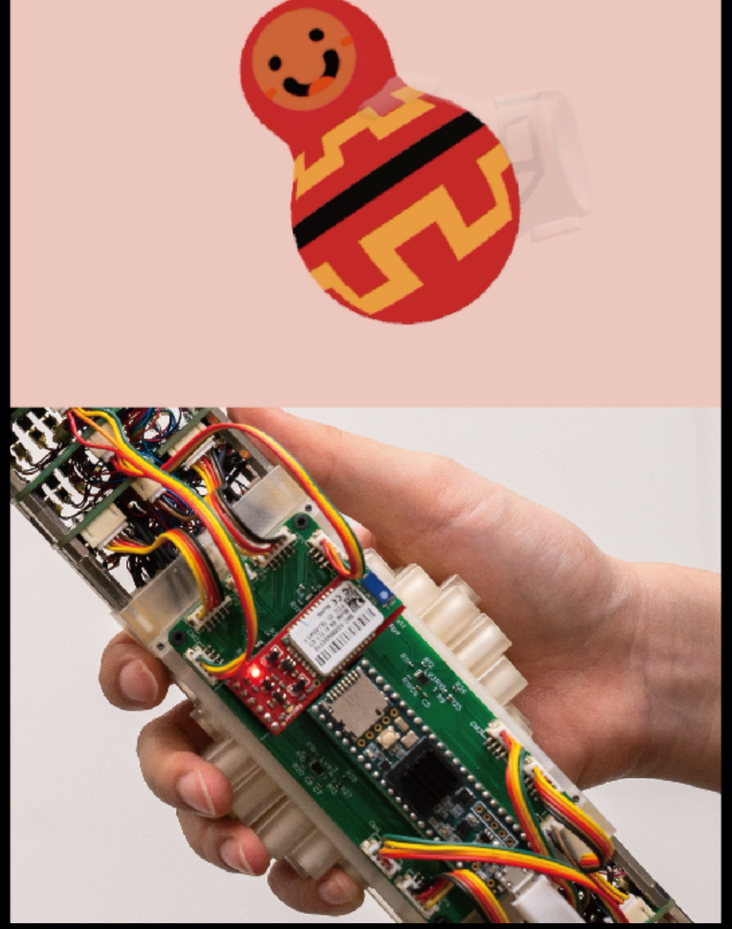
Applications

Rendering Static Shapes

a: glass (linear)

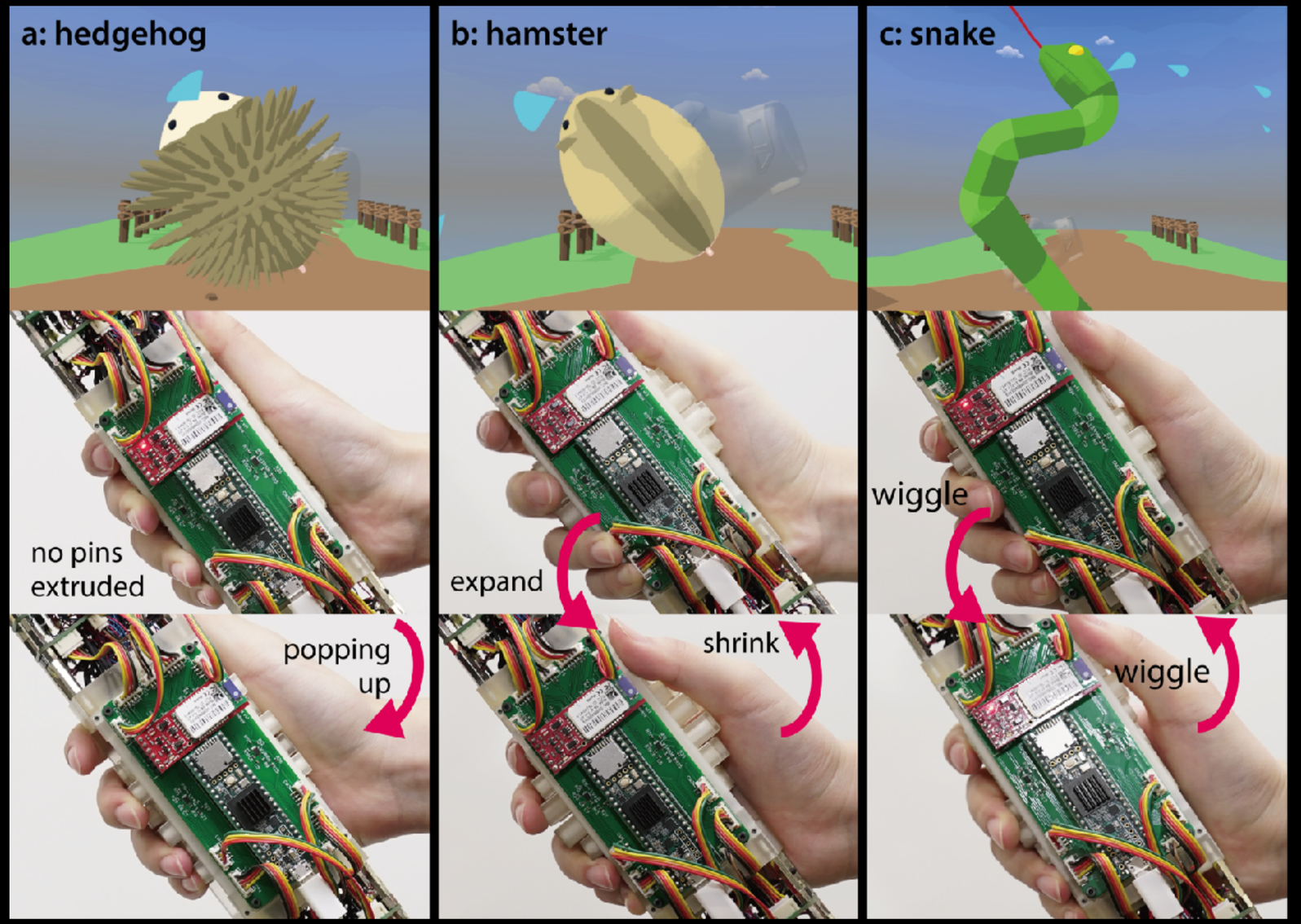


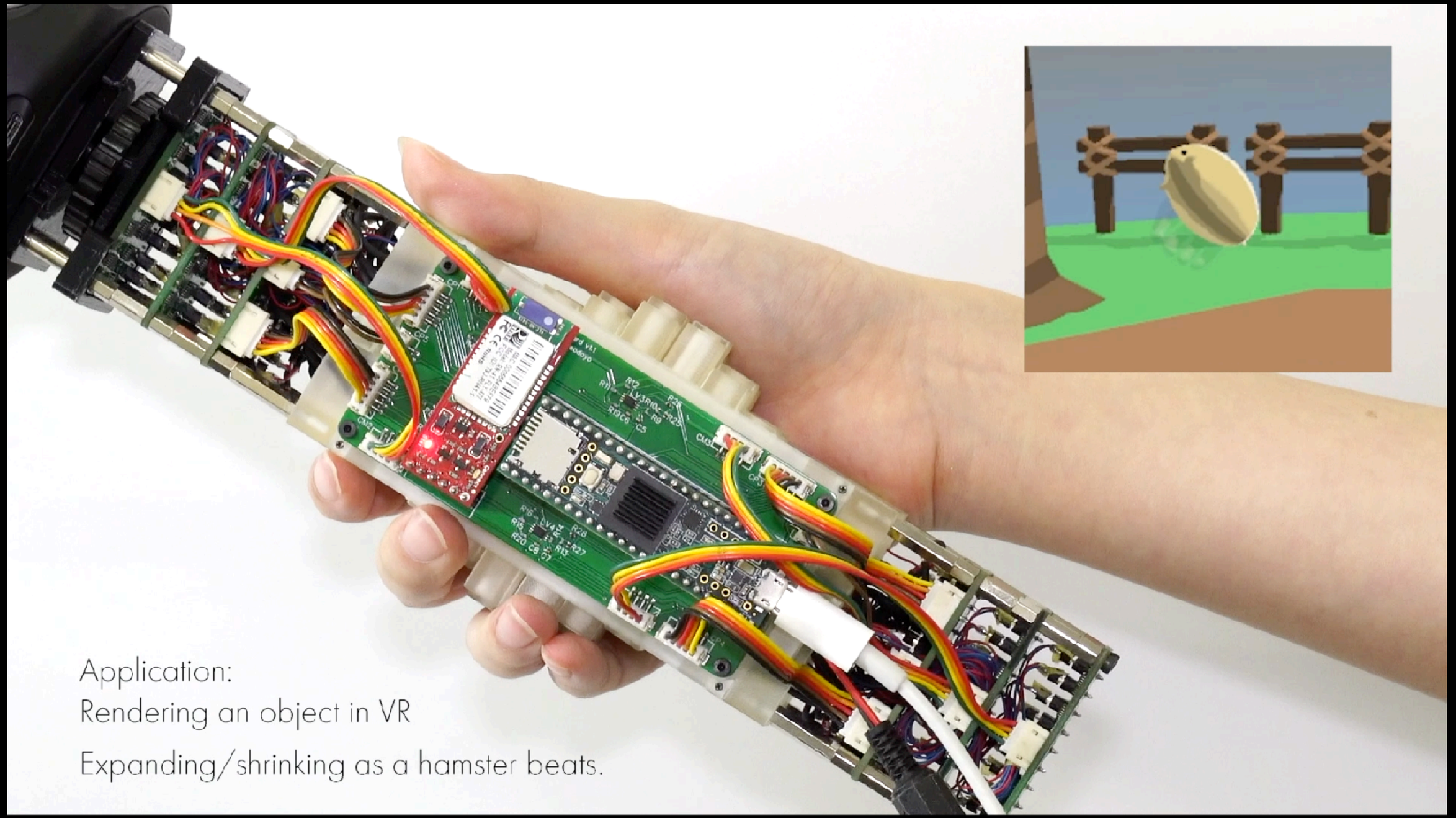
b: matryoshka (convex)

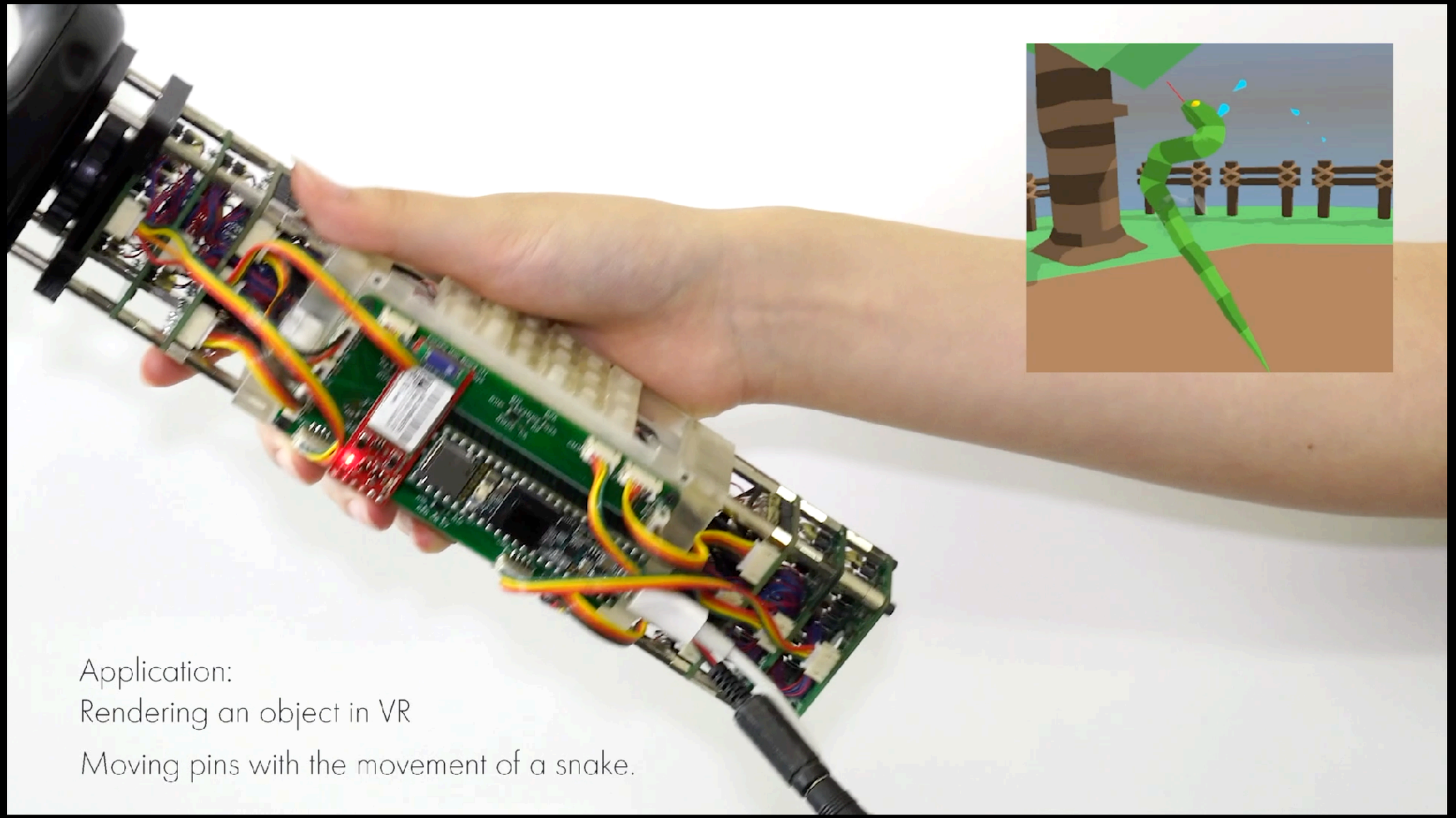


c: trophy (concave)

Rendering Dynamic Shapes




Application:
Rendering an object in VR
Expanding/shrinking as a hamster beats.


Application:
Rendering an object in VR
Moving pins with the movement of a snake.

Limitation & Future Work

“Slow” pin speed

“Small” number of pins

“Limited” display area

“Lack” of touch detection capability

"Slow" pin speed

"Small" number of pins

"Limited" display area

→ *Visuo-haptic illusion*[2]

"Lack" of touch detection capability

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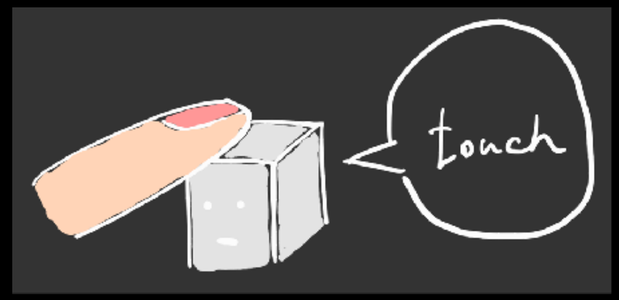

"Lack" of touch detection capability → Embed touch sensors into pins

Conclusion

Contributions

1. Concept of ***handheld*** pin-based shape display
   - Realtime rendering of 2.5D shapes in hand by pin arrays
   - Providing skin contact sensation on user's hand in VR
2. Design of handheld pin-based shape display, named PoCoPo
   - *Miniaturization*: placing actuators & circuits so that they do not interfere with hand
   - *Non-backdrivability*: worm-gear mechanism
3. Evaluations to understand the capability of PoCoPo
   - Study 1: users can distinguish shapes with average *88.5%*
   - Study 2: users tend to *feel visual size larger than physical size*

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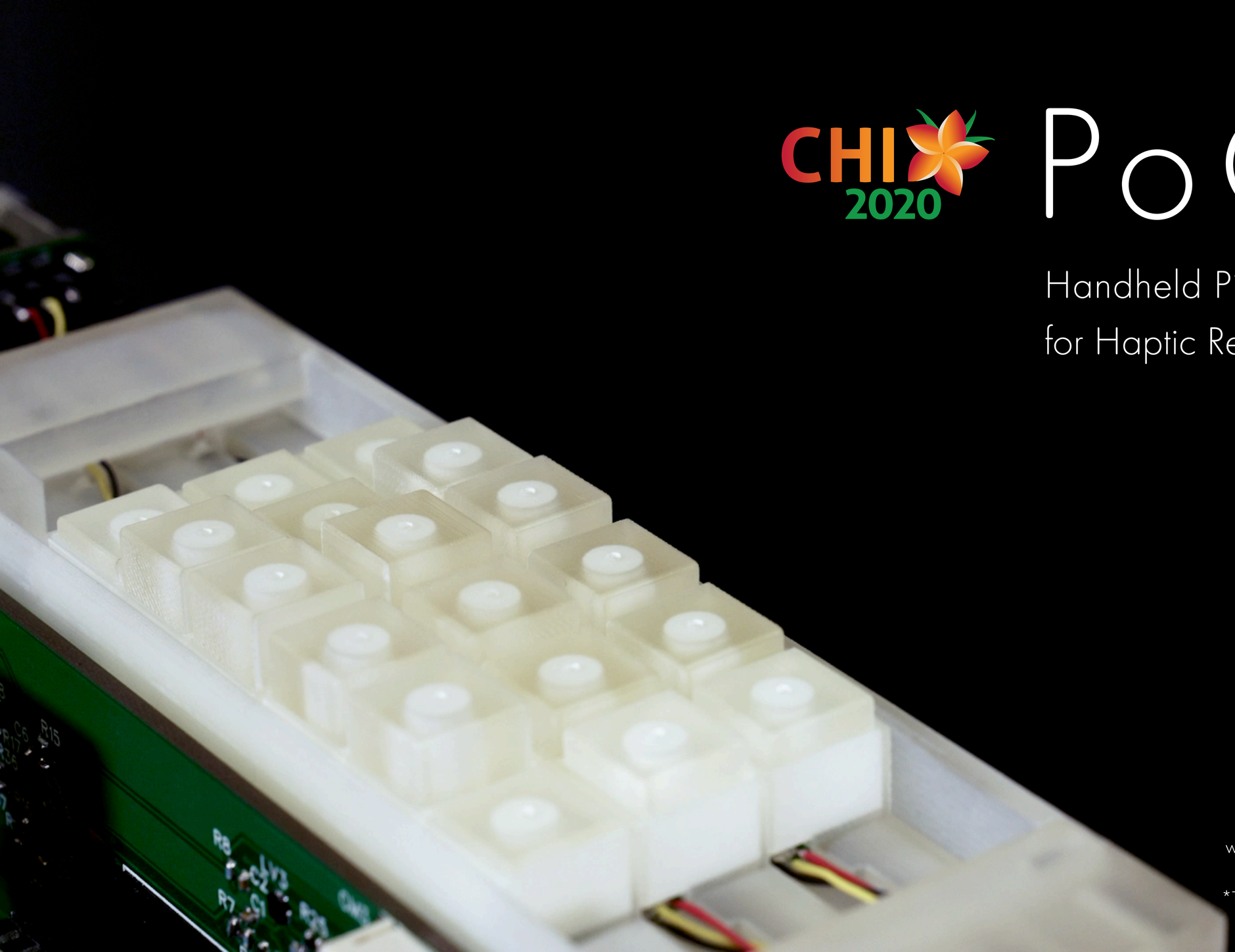

CHI 2020

PoCoPo

Handheld Pin-based Shape Display for Haptic Rendering in Virtual Reality

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